MSC-PA-R-69-2
Supplement 4

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 9 MISSION REPORT

PERFORMANCE OF THE COMMAND AND SERVICE MODULE REACTION CONTROL SYSTEM

DISTRIBUTION AND REFERENCING

This paper is not suitable for general distribution or referencing. It may be referenced only in other working correspondence and documents by participating organizations.

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
March 1970

MSC-PA-R-69-2
Supplement 4

APOLLO 9 MISSION REPORT
SUPPLEMENT 4

PERFORMANCE OF THE COMMAND AND SERVICE MODULE REACTION CONTROL SYSTEM

PREPARED BY

Propulsion and Power Division

APPROVED BY

James A. McDivitt
Colonel, USAF
Manager, Apollo Spacecraft Program

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
March 1970

PREFACE

This report has been prepared as Supplement 4 to the Apollo 9 Mission Report (MSC-PA-R-69-2). This report provides additional in depth analysis beyond the scope of the normal data contained in the basic mission report.

THERMOCHEMICAL TEST AREA
PROPULSION AND POWER DIVISION
NASA - MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

APOLLO 9 MISSION REPORT

PERFORMANCE OF THE CSM RCS DURING THE AS-504/SC-104/LM-3 MISSION (APOLLO 9)

DOC. NO. MSC-PA-R-69-2 Supplement 4 DATE May 15, 1969

PREPARED BY:	W. Nelson Lingle W. Nelson Lingle
	Lonnie W. Jenkins Lonnie W. Jenkins
	Julian W. Jones Julian W Jones
APPROVED BY:	(SECTION) Reaction Control Chester A Vaughan
APPROVED BY:	(BRANCH OFFICE) Auxiliary Propulsion and Pyrotechnics Henry O. Pohl
APPROVED BY:	(DIVISION) Propulsion and Power Richard B Ferguson for JGT
APPROVED BY:	

NO. OF PAGES 68

REVISIONS

DATE	AUTHOR	APPROVALS				CHG. LETTER
		SECTION	BRANCH	DIVISION		

DOC. NUMBER MSC-PA-R-69-2 Supplement 2

MSC FORM 360A (JAN 67)

CONTENTS

TABLES

FIGURES

ABBREVIATIONS

accel	acceleration
AOH	Apollo Operations Handbook
APS	ascent propulsion system
AS	Apollo Saturn
assy	assembly
CSM	command and service module
CW	caution and warning
CM	command module
DPS	descent propulsion system
DTO	detailed test objective
EVA	extravehicular activity
G.m.t.	Greenwich mean time
g.e.t.	ground elapsed time
G&N	guidance and navigation
He	helium
iso	isolation
KSC	Kennedy Space Center
LH_2	liquid hydrogen
LO_2	liquid oxygen
LM	lunar module
MMH	monomethylhydrazine
N_2O_4	nitrogen tetroxide
NR	North American Rockwell

oxid	oxidizer
O/F	oxidizer to fuel
PCM	pulse code modulation
ppm	parts per million
P	pitch
P/T	pressure-temperature
PVT	pressure-volume-temperature
PIPA	pulse integrated pendulous accelerometer
RCS	reaction control system
R	roll
S/S	samples per second
S-IVB	Saturn-IVB
sep	separation
S/N	serial number
SM	service module
SPS	service propulsion system
SC	spacecraft
SLA	spacecraft lunar adapter
TCS	thermal control system
TLI	translunar injection
Y	yaw

PERFORMANCE OF THE CSM RCS DURING THE

AS-504/SC-104/LM-3 MISSION (APOLLO 9)

By W. Nelson Lingle, Lonnie W. Jenkins,
and Julian Jones

SUMMARY

The Apollo 9 vehicle was launched from Kennedy Space Center (KSC) launch complex 39A at 16:00:00.7 Greenwich mean time (G.m.t.) on March 3, 1969. The spacecraft landed in the Atlantic recovery area at 17:00:54 G.m.t. on March 13, 1969.

The service module (SM) and the command module (CM) reaction control system (RCS) performed satisfactorily throughout the mission. The only anomaly which occurred was an inadvertent isolation valve closure during command and service module/lunar module Saturn S-IVB (CSM/LM S-IVB) separation. The valves were later opened by the crew and remained open during the remainder of the mission. The cause for the valve closure has been determined to be the shock from the CSM/SLA separation pyrotechnic devices.

The SM and CM RCS fuel loading was performed on February 4, 1969, and oxidizer loading was performed on February 8, 1969. Approximately 18 pounds of oxidizer (9 pounds per system) were off-loaded from the CM RCS. This was to prevent raw oxidizer from contacting the parachutes and risers during the propellant dump operation. Helium servicing of both SM and CM RCS was performed on February 24, 1969. Prior to launch, a helium leak was detected at the high-pressure helium pressure transducer in quad C. The quad door was opened without deservicing the propellant and the transducer seal replaced. No launch schedule slip was required. Static-firing of the SM RCS engines on the pad was not performed.

The SM RCS helium pressurization system maintained the helium and propellant manifold pressures constant at 180 ± 6 psia. No helium or propellant leakage was detected from the SM RCS during the flight.

Evaluation of spacecraft (SC) body rates indicated normal RCS performance throughout the flight.

A total of 790 pounds of SM RCS propellant was used during the mission. The predicted usage, as corrected for flight plan changes, was 598 pounds. Most of the discrepancy between actual and predicted usage came while the quad C propellant isolation valves were closed and during the undocked LM-active period. The secondary fuel tank helium isolation valves (VW valves) on all quads were opened prior to CM-SM separation although an empty primary tank had not been indicated by a drop in the fuel manifold pressure.

An estimate for the total number of firings for the 16 SM RCS engines is 57 000.

Thermal control of the SM RCS was satisfactory throughout the flight. The maximum temperature reached due to boost heating was 145° F on quad D. The primary heaters on all quads were activated shortly after orbit insertion and remained on for the remainder of the mission. At 3:07:00 ground elapsed time (g.e.t.), during the period that the quad C isolation valves were closed, the quad A package temperature reached 209° F. However, during times of low engine activity, the primary heaters maintained the package temperature between 117° and 141° F. The SM RCS helium tank temperatures ranged from 49° to 82° F.

Both manual and automatic control were used during entry. Approximately 12 seconds after CM-SM separation, system 2 was deactivated and the remainder of the entry was performed using system 1 only. Evaluation of the spacecraft body rates indicates normal CM RCS performance.

A total of 27.5 pounds of CM RCS propellant was used for entry (27 pounds from system 1 and 0.5 pound from system 2). The remaining 217.5 pounds were burned through the engines during the depletion burn following main parachute deployment. The depletion burn started at 240:56:26 g.e.t. and the helium system blowdown and propellant line purge was initiated at 240:57:36. The propellant isolation valves were closed at 240:58:17.

The CM RCS helium tank temperatures remained between 54° and 74° F prior to system activation. The temperature of the instrumented CM RCS injectors was approximately 50° F or higher at all times and the CM valve warmup procedure was not required.

INTRODUCTION

Apollo 9 was the third manned Apollo mission, the second manned Saturn V mission, and the first manned LM mission. Lift-off occurred at 16:00:00.7 G.m.t. on March 3, 1969, and the mission duration was approximately 241 hours. The spacecraft landed in the Atlantic at 17:00:54 G.m.t. on March 13, 1969. The crew consisted of James McDivitt, commander; David Scott, command module pilot; and Russell Schweickart, lunar module pilot.

This was designated as a D-type mission. The primary purpose was to evaluate the LM systems performance and to perform selected CSM/LM operations. The major spacecraft events during the mission are listed in the following six periods of activity:

1. Launch, pre-translunar injection (TLI) procedure exercise, transposition and docking, CSM/LM ejection, docked service propulsion system (SPS) burn, S-IVB unmanned restart

2. Three docked SPS burns

3. Lunar module systems evaluation, docked descent propulsion system (DPS) burn, docked SPS burn

4. Extravehicular activity (EVA)

5. Lunar-module-active rendezvous, unmanned ascent propulsion system (APS) long-duration burn to depletion

6. Command and service module solo activities including two SPS orbit-shaping burns, a deorbit burn, and Atlantic landing

Various detailed test objectives (DTO's) were defined for the CSM RCS. These are covered in detail in the Mission Requirements Document, SPD8-R-005, Revision 1, Change A, dated January 21, 1969. Briefly, these DTO's were as follows:

1. S1.26 Orbital Navigation/Landmark Tracking — Determine SM RCS propellant consumption.

2. S7.29 Exhaust Effects/CSM — Obtain data on the effects of the tower jettison motor, S-II retro, and SM RCS exhaust on the CSM.

3. M17.17 LM Environmental and Propulsion Thermal Effects — Verify performance of LM passive thermal design when exposed to natural and propulsion-induced environments.

4. P20.24 CSM Active Docking — Demonstrate CSM docking with S-IVB/SLA/LM and determine SM RCS propellant consumption.

5. P20.25 LM Ejection from SLA — Demonstrate CSM/LM ejection from the SLA using the SM RCS.

6. P20.26 LM/CSM Undocking — Demonstrate LM/CSM undocking using SM RCS and compute CSM accelerations and SM RCS propellant consumption.

7. P20.29 LM Jettison — Perform a pyrotechnic separation of the LM and CSM and compute CSM acceleration and SM RCS propellant consumption.

SERVICE MODULE RCS FLIGHT PERFORMANCE

System Configuration

A schematic of the SC 104 SM RCS is shown in figure 1, and a view of the helium pressurization and propellant system on the interior side of quad panels B and D is shown in figure 2. Quads A and C are mirror images of quads B and D. The relative locations of the quads within the SM are shown in figures 3(a), 3(b), 3(c), and 3(d). The SM RCS quad engine package is shown in figure 4 and a cross section of the engine is shown in figure 5.

The only difference between the SC 103 and SC 104 RCS was the addition of an isolation valve in the helium line to the secondary fuel tanks on the SM quads. The purpose of this normally closed valve is to determine when the primary fuel tank is empty by a pressure decay in the fuel manifold pressure. When this occurs, the isolation valve (VW valve) is manually opened. This allows the propellant-remaining calculation to be updated to include the known volume of the secondary fuel tank, thereby increasing the accuracy of the measurement.

A summary of vehicle changes from SC 101 to SC 108 is presented in table I.

Instrumentation

The SC 104 SM RCS instrumentation list is shown in table II. Instrumentation locations are shown in figures 1, 2, 3, and 4. The quad B helium tank pressure transducer, SR-5002, was erratic for the duration of the mission. The output of this transducer would jump approximately 250 psi and then return to normal. This occurred about three times per day. No cause for the erratic readings has been determined.

Caution and Warning System

The SC 104 SM RCS caution and warning (CW) switch limits and redlines are shown in table III. The nominal quad A package temperature CW limit of 206° F was reached during the transposition and docking period when the quad C isolation valves were closed. The redline limit of 210° F was not reached.

Prelaunch Activity

The SM RCS fuel (MMH) was loaded on February 4, 1969, and the oxidizer (N_2O_4) was loaded on February 8, 1969. Helium servicing of the SM quads was accomplished on February 24, 1969. A detailed breakdown of propellant and helium servicing is shown in table IV. Prior to launch, a leak was detected at the quad C high-pressure helium manifold pressure transducer. The quad door was opened without being deserviced and the seal on the transducer replaced. The work was accomplished during a built-in hold in the countdown and did not require a launch schedule slip. The leakage did not reoccur during the mission.

The SM RCS was not static-fired on the launch pad.

Flight Time Line

A listing of the times of major SM RCS events and activities of interest during the mission is given in table V. Because of a lack of data, several of the times are approximate. Most of these maneuvers were done during times that only low-bit-rate data were available.

Propulsion Performance

Table VI shows the velocity change obtained from several SM RCS translation maneuvers. The velocity change was calculated by summing the impulse of the four +x translation engines and then subtracting the summed impulse of the -x translation engines which were required for attitude control during the translation. Engine on times obtained from the bilevel data and the acceptance test values for the RCS engine thrusts were used for this calculation. These data are compared with the measured velocity changes as calculated from the SC accelerometer (PIPA) data in table VI. The control mode used for the maneuvers is also shown in table VI.

Table VII identifies the accelerations achieved during various RCS maneuvers. Angular accelerations during translational maneuvers and along the minor axes during rotational maneuvers can be attributed to center-of-gravity offset and force vector cross coupling. The difference in accelerations during rotational maneuvers with identical vehicle masses can be attributed to propellant slosh. The magnitude of the pitch accelerations during +pitch maneuvers was consistently higher than those during the -pitch maneuvers for approximately identical vehicle masses. This is caused by the location of the CSM umbilical directly above the -x/-P engine of quad C (fig. 6), which resulted in an effective force reduction of approximately 20 percent. This 20 percent is based on theoretical calculated values as well as the rate data. All other accelerations indicate nominal performance by all 16 SM RCS engines throughout the mission.

Helium Pressurization System

The SM RCS helium pressurization systems for the four quads functioned normally throughout the flight. Following helium servicing and prior to the first SM RCS engine firings, the regulators maintained lockup of approximately 195 psia, approximately 15 psi higher than the specification value for lockup pressure. This is because the regulators are referenced to atmospheric pressure while on the pad as opposed to the vacuum of deep space. At first SM RCS usage, during CSM/S-IVB/LM separation, the manifold pressures decreased to normal regulated pressures and remained constant at 180 ± 6 psia for the duration of the flight. Helium source temperatures and pressures for the four quads during the flight are shown in figures 7 and 8. Preflight checkout data for selected SM helium system components are shown in table VIII.

Propellant Feed System

With the exception of one anomaly, the SM RCS propellant feed system functioned normally throughout the mission and no indication of propellant leakage was noted. During transposition and docking with the S-IVB/LM, the primary and secondary propellant isolation valves on quad C and the secondary propellant isolation valves on quad D were found to be in the closed position. The valves were opened prior to CSM/S-IVB/LM docking and remained open for the duration of the mission.

Opening of the helium isolation valves (VW valves) in the pressurization line to the secondary propellant tanks was intended to take place when the fuel manifold pressure decreased from 180 to 150 psia. However, this did not occur since sufficient propellant was not consumed to deplete the primary fuel tank in either of the four quads. All four VW valves were opened approximately 3 hours prior to CM-SM separation to assure that propellant would be available for the SM jettison maneuver.

Engines

All performance data indicate proper engine performance during the mission. Due to a lack of complete data coverage, it is impossible to determine the exact values for total engine burn time and total number of pulses. However, a rough estimate based on the weight of propellant consumed is 2000 seconds total burn time and 57 000 total pulses. This does not include the SM jettison burn since propellant consumption data are not available after separation.

Thermal Control

The SM RCS thermal control system (TCS) performed satisfactorily throughout the mission. The TCS operational parameters for SC 104 are given in table IX, and system checkout data are shown in table X.

The spacecraft was launched with the engine package heaters "off" on all four quads. The primary heater system on each quad was activated at approximately 00:15:00 g.e.t., shortly after orbit insertion. The maximum quad package temperature attained as a result of boost heating was 145° F on quad D, as shown in figure 9(a). The Apollo 9 launch trajectory is shown in figure 10.

The activation of the primary heaters on quads A and C can be seen in figure 9(b) as a sudden discontinuity in the temperature-time plot at approximately 00:15:00 g.e.t. The primary heaters of quads B and D did not come on at this time because the primary heater thermostats on quads B and D are located near the upfiring (-X) engine. The aerodynamic heat input to the engine package from launch is primarily through the upfiring and two roll engines. Therefore, the thermostats on quads B and D were warmer than the temperature indicated on the quad package temperature sensor. The thermostats were evidently warm enough to prevent heater operation when the switches were placed in the "primary" position. Conversely, the primary thermostats on quads A and C, which are located near the downfiring (-X) engines, were cooler than indicated by the package temperature sensors, and did not reach a temperature at which they would open. The heaters on quads A and C, therefore, came on when the switches were placed in the "primary" position.

During the transposition and docking period, while the quad C isolation valves were closed, the four package temperatures reached levels of 209°, 196°, 173°, and 186° F, respectively. The 209° F on quad A was sufficient to trigger the caution and warning switch although it was not above the 210° F redline. The high temperature on quad A resulted from the fact that left translation was being requested with quad C unable to provide impulse because of the closed isolation valves. This resulted in counterclockwise roll which caused the control system to correct by firing clockwise roll. This means that opposing roll thrusters on quad A would fire and cause the temperature to increase. The temperature profile during this period is shown in figures 9(a) and 9(b).

During the remainder of the mission the TCS operated normally, and except for periods of high engine activity, the heaters cycled normally between 117° and 141° F. A comparison of the primary thermostat switching limits observed during the flight with preflight checkout data is shown in table XI. Typical SM RCS TCS cycling data are shown in figures 9(a) and 9(b). Due to a lack of complete data coverage, detailed cycling information is not available.

The SM RCS helium tank temperatures are shown in figure 8. The temperatures ranged from 49° to 82° F, primarily depending on vehicle orientation. The helium tanks for quads C and D were consistently warmer than those for quads A and B due to the fuel cell heat from the adjacent SM bay. Fuel cell locations can be seen in figure 3.

Propellant Utilization and Quantity Gaging

The total propellant consumption and the predicted consumption as adjusted for flight plan changes are shown in figure 11(a). During the transposition and docking maneuvers, while quad C was isolated, the actual usage exceeded the predicted usage by approximately 50 pounds. Also, during the undocked LM-active period between 92 and 99 hours g.e.t., approximately 115 pounds were expended above the predicted value. At the end of the mission, the actual usage exceeded the predicted usage by approximately 140 pounds.

The propellant usage for each quad is shown in figure 11(b). The maximum mismatch in propellant expended between the quads was maintained within 35 pounds by selectively varying combinations of one-, two-, and four-jet roll maneuvers and two- and four-jet translation maneuvers. This was also done in an attempt to keep the quads above the stabilization and control system (SCS) deorbit redlines. Late in the mission quads A and C were slightly below this redline, so the last three ullage burns were two-jet quads B and D maneuvers.

The SM RCS propellant quantity was determined by two methods during the flight. The PVT ground computer program utilized pressure, volume, and temperature considerations and was available only on the ground. The P/T sensor, which gives propellant quantity as a function of helium tank pressure and temperature, was displayed in the vehicle in terms of percent full scale of a 0 to 5 voltmeter, as well as being telemetered.

The PVT program was assumed to be the correct value for propellant expended. The quoted accuracy of this program is ±6 percent due to instrumentation inaccuracies of the inputs to the program, oxidizer-to-fuel (O/F) ratio shift, and the differential between helium tank and propellant ullage temperatures. The output of the P/T sensor was designed to read 100 percent when the helium tank pressure was 4150 psia at 70° F and 0 percent when the pressure was 2250 psia at 70° F. The correct theoretical value of helium tank pressure at propellant depletion is 2450 psia at 65° F. To correct the P/T sensor readings for this end-point error, as well as for compressibility effects, system temperature variability, and propellant vapor pressure effects, the nomogram shown in figure 12 was used. Figure 11(b) shows the relation between the propellant expended as derived from the PVT program as well as from the corrected P/T sensor readings. Table XII shows the relations between the usable propellant remaining as derived from the PVT program, uncorrected P/T sensor, and corrected P/T sensor. The variation between PVT and P/T readings is given for seven random times during the mission.

COMMAND MODULE RCS FLIGHT PERFORMANCE

System Configuration

A schematic of the SC 104 CM RCS is shown in figure 13. This system differs from the SC 101 and SC 103 configurations only in the location of the low-pressure helium manifold pressure transducer. The location was changed from downstream of the check valves in both the fuel and oxidizer manifolds to upstream of the check valves. This negates the possibility of determining which propellant was depleted first during the depletion burn since the transducer is now in the common manifold between the two tanks and the regulators.

A typical CM RCS engine is shown in figure 14.

Instrumentation

The SC 104 CM RCS instrumentation list is shown in table XIII. Instrumentation locations are shown in figures 13 and 14. No CM RCS instrumentation anomalies occurred during the Apollo 9 mission.

Caution and Warning System

The SC 104 CM RCS caution and warning switch limits are shown in table XIV. None of these limits were reached during the mission.

Preflight Activity

The CM RCS fuel (MMH) was loaded on February 4, 1969, and the CM RCS oxidizer (N_2O_4) was loaded on February 8, 1969. A total of 245.0 pounds of propellants was loaded in the two systems. Helium servicing of the CM RCS was accomplished on February 24, 1969. A detailed breakdown of propellant and helium servicing per system is shown in table XV.

Approximately 9 pounds of oxidizer were off-loaded from each CM RCS system to prevent raw oxidizer from contacting the parachutes and risers during the propellant depletion burn operation following entry. No systems leakage was observed prior to launch.

Flight Time Line

A listing of the times of major CM RCS events and activities of interest during the mission is given in table XVI.

Propulsion Performance

Table XVII lists the measurable accelerations for all significant maneuvers for which data are available prior to the 400 000-foot altitude level. In this table, the measured accelerations are compared with the theoretical rates. This comparison indicates nominal CM RCS performance.

Both manual and automatic control were used during entry. Both systems were active at CM-SM separation; however, system 2 was deactivated approximately 15 seconds later at 240:36:18.3 g.e.t. The remainder of the entry was made using system 1 only.

Helium Pressurization System

The CM RCS pressurization system functioned normally throughout the flight. The system temperatures and pressures from launch through system activation are shown in figure 15. Throughout this time period the helium manifold pressures remained essentially constant, indicating no system leakage. The system 1 helium manifold pressure ranged from 47 to 49 psia and system 2 from 45 to 46 psia.

The CM RCS systems were activated at 239:59:42.5 g.e.t., approximately 36 minutes before CM-SM separation. The helium isolation squib valves operated normally at system activation. The helium tank pressure and temperature at activation are shown in figure 16. The initial helium tank pressure drop at system activation for system 1 was approximately 845 psia and for system 2 was 800 psia. After thermal stabilization the stable pressure decrease for systems 1 and 2 was 630 psia and 640 psia, respectively. The relief valve burst discs were not ruptured at activation.

At system activation the fuel and oxidizer tank pressures for both systems locked up at 295 ± 2 psia and the regulators maintained this pressure range through the active firing portion of the entry.

The CM RCS helium source pressures and temperatures from CM-SM separation through landing are shown in figures 17(a) and 17(b). The helium source pressures during the propellant depletion burn and helium purge operations are shown in figure 18. Helium manifold pressures during propellant depletion burn and helium purge are shown in figure 19. No CM RCS helium system leakage was noted following systems activation. Selected preflight checkout data for CM RCS helium pressurization system components are shown in table XVIII.

Propellant System

The propellant system functioned normally throughout the flight. No propellant leakage was noted at any period. The propellant isolation valves were opened prior to systems activation. Due to the relocation of the low-pressure helium manifold pressure transducers, it was not possible to determine which propellant was depleted first during the depletion burn. However, the onboard movies indicate a small amount of free oxidizer around the SC during the general time period of the depletion burn. Also, several parachute suspension lines recovered after the landing indicated that they had been slightly damaged by what could have been CM RCS oxidizer. The oxidizer could possibly have been released during the purge of the propellant manifold lines and is not considered to be a serious problem.

The CM RCS propellant isolation valves were closed at 240:58:17 g.e.t., approximately 3 minutes prior to landing.

Engines

All data indicate proper engine performance during the entry. A total of 79.42 seconds of burn time and 499 pulses were accumulated on the 12 CM RCS engines, exclusive of the steady-state propellant depletion burn which lasted approximately 70 seconds. The CM RCS engine firing summary is shown in table XIX.

Thermal Control

The CM RCS helium tank temperatures ranged between 54° and 74° F from launch through system activation, as shown in figure 15. The six instrumented CM RCS engine injector temperatures, read by the crew on the onboard meter, remained approximately 50° F (upper limit of the meter) from launch through CM RCS activation. Consequently, the CM RCS valve warmup procedure, which was to be used if any injector fell below 28° F, was not required.

Propellant Utilization

As shown in figure 20, a total of 27.5 pounds of CM RCS propellant was used prior to the propellant depletion burn (27 pounds from system 1 and 0.5 pound from system 2). Figure 20 is based on PVT calculations; the apparent negative propellant usage is due to the thermal stabilization of the system after periods of high usage.

SPACECRAFT DEACTIVATION

On March 16, 1969, at 0900 hours eastern standard time, the U.S.S. Guadalcanal docked at pier 12, Norfolk Naval Air Station. The CM was off-loaded and located in hangar LP-2 at approximately 1030 hours. The CM RCS fuel deactivation lasted from 1500 hours on March 16, 1969, to 0700 hours on March 18, 1969. Oxidizer deactivation was accomplished between 1700 hours on March 17, 1969, and 1900 hours on March 18, 1969.

Although a small amount of helium pressure remained, essentially no propellants were found in the CM RCS during deactivation. After purging, the sample of the gaseous nitrogen purge fluid indicated no detectable N_2O_4 or MMH. Less than 10 ppm of flush fluid (Freon TF) were found in the sample from the oxidizer side. The samples from the fuel side of systems 1 and 2 indicated 120 and 56 ppm of flush fluid (isopropyl alcohol), respectively.

The postflight examination revealed that the CM RCS relief valve burst discs were not ruptured and the protective covers were still intact. Also, all engine, helium, fuel, and oxidizer panels appeared to be in good condition with no visible anomalies.

The CM, aboard a C133 B aircraft, departed Norfolk Naval Air Station at 0835 hours eastern standard time on March 20, 1969, to North American Rockwell (NR), Downey, California.

TABLE I.- SERVICE MODULE RCS CONFIGURATION CHANGE SUMMARY

Parameter	AS 205/ CSM 101	AS 503/ CSM 103	AS 504/ CSM 104	AS 505/ CSM 106	AS 506/ CSM 107	AS 507/ CSM 108
Auxiliary helium pressurization valve upstream of secondary fuel tank	No	No	Yes	Yes	Yes	Yes
Capability to electrically isolate individual SM RCS engines	No	Yes	Yes	Yes	Yes	Yes
Cabin display of SM RCS helium tank temperature	No	Yes	Yes	Yes	Yes	Yes
Primary tank outlet temperatures measured	Yes	No	No	No	No	No
Secondary heater thermostats range ($77 \pm 7°$ F to $104 \pm 14°$ F) switch limits	Yes	Yes	Yes	No	No	No
Secondary heater thermostats range ($120 \pm 5°$ F to $129 \pm 5°$ F) switch limits	No	No	No	Yes	Yes	Yes
Panel insulation multilayer aluminized Mylar encapsulated with H-film	Yes	No	No	No	No	No
Panel insulation multilayer aluminized H-film	No	Yes	Yes	Yes	Yes	Yes
Look-angle blankets installed	No	Yes	Yes	Yes	Yes	Yes

TABLE II.- SERVICE MODULE RCS INSTRUMENTATION LIST

Measurement number	Parameter	Telemetry (a)	Cabin display	Response, S/S	Data range
SR5001P	Helium tank pressure, quad A	PCM+	Yes	1	0 to 5000 psia
SR5002P	Helium tank pressure, quad B	PCM+	Yes	1	0 to 5000 psia
SR5003P	Helium tank pressure, quad C	PCM+	Yes	1	0 to 5000 psia
SR5004P	Helium tank pressure, quad D	PCM+	Yes	1	0 to 5000 psia
SR5013T	Helium tank temperature, quad A	PCM+	No	10	0 to 100° F
SR5014T	Helium tank temperature, quad B	PCM+	No	10	0 to 100° F
SR5015T	Helium tank temperature, quad C	PCM+	No	10	0 to 100° F
SR5016T	Helium tank temperature, quad D	PCM+	No	10	0 to 100° F
SR5025Q	Propellant quantity, quad A	PCM+	Yes	1	0 to 100 percent
SR5026Q	Propellant quantity, quad B	PCM+	Yes	1	0 to 100 percent
SR5027Q	Propellant quantity, quad C	PCM+	Yes	1	0 to 100 percent
SR5028Q	Propellant quantity, quad D	PCM+	Yes	1	0 to 100 percent
SR5065T	Package temperature, quad A	PCM	Yes	1	0 to 300° F
SR5066T	Package temperature, quad B	PCM	Yes	1	0 to 300° F
SR5067T	Package temperature, quad C	PCM	Yes	1	0 to 300° F
SR5068T	Package temperature, quad D	PCM	Yes	1	0 to 300° F
SR5729P	Helium manifold pressure, quad A	PCM+	Yes	10	0 to 400 psia
SR5776P	Helium manifold pressure, quad B	PCM+	Yes	10	0 to 400 psia
SR5817P	Helium manifold pressure, quad C	PCM+	Yes	10	0 to 400 psia
SR5830P	Helium manifold pressure, quad D	PCM+	Yes	10	0 to 400 psia
SR5737P	Fuel manifold pressure, quad A	PCM+	No	10	0 to 300 psia
SR5784P	Fuel manifold pressure, quad B	PCM+	No	10	0 to 300 psia
SR5822P	Fuel manifold pressure, quad C	PCM+	No	10	0 to 300 psia
SR5823P	Fuel manifold pressure, quad D	PCM+	No	10	0 to 300 psia
SR5733P	Oxidizer manifold pressure, quad A	PCM+	No	10	0 to 300 psia
SR5780P	Oxidizer manifold pressure, quad B	PCM+	No	10	0 to 300 psia
SR5820P	Oxidizer manifold pressure, quad C	PCM+	No	10	0 to 300 psia
SR5821P	Oxidizer manifold pressure, quad D	PCM+	No	10	0 to 300 psia
SR5046X	Sec prop iso[b] valves position, quad A	No	Yes	1	On/off event
SR5047X	Sec prop iso valves position, quad B	No	Yes	1	On/off event
SR5048X	Sec prop iso valves position, quad C	No	Yes	1	On/off event
SR5049X	Sec prop iso valves position, quad D	No	Yes	1	On/off event
SR5050X	Pri prop iso[c] valves position, quad A	No	Yes	1	On/off event
SR5051X	Pri prop iso valves position, quad b	No	Yes	1	On/off event
SR5052X	Pri prop iso valves position, quad C	No	Yes	1	On/off event
SR5053X	Pri prop iso valves position, quad D	No	Yes	1	On/off event

[a]Measurements labeled PCM are available only during periods of high-bit-rate data transmission. Measurements labeled PCM+ are available during periods of high- or low-bit-rate data transmission.

[b]Secondary propellant isolation.

[c]Primary propellant isolation.

TABLE III.- SERVICE MODULE RCS CAUTION AND WARNING SWITCH LIMITS

Measurement number	Parameter	Hi/Lo	Redline	CW limits	
				Spec	Actual
SR5737P	Fuel manifold pressure, quad A	Hi Lo	220 psia 75 psia	215 psia 145 psia	205 psia 147 psia
SR5784P	Fuel manifold pressure, quad B	Hi Lo	220 psia 75 psia	215 psia 145 psia	207 psia 149 psia
SR5822P	Fuel manifold pressure, quad C	Hi Lo	220 psia 75 psia	215 psia 145 psia	207 psia 150 psia
SR5823P	Fuel manifold pressure, quad D	Hi Lo	220 psia 75 psia	215 psia 145 psia	206 psia 149 psia
SR5065T	Package temperature, quad A	Hi Lo	210° F 65° F	205° F 75° F	206° F 85° F
SR5066T	Package temperature, quad B	Hi Lo	210° F 65° F	205° F 75° F	209° F 87° F
SR5067T	Package temperature, quad C	Hi Lo	210° F 65° F	205° F 75° F	207° F 87° F
SR5068T	Package temperature, quad D	Hi Lo	210° F 65° F	205° F 75° F	208° F 86° F

TABLE IV.- SERVICE MODULE RCS PROPELLANT AND HELIUM SERVICING DATA

Parameter	Quad A	Quad B	Quad C	Quad D
Primary fuel tank load, lb	69.5	69.7	70.3	70.3
Secondary fuel tank load, lb	40.3	39.6	40.7	40.3
Total fuel load, lb.	109.8	109.3	111.0	110.6
Total oxidizer load, lb	223.1	225.4	226.2	225.2
Loaded O/F ratio	2.03	2.06	2.04	2.04
Total propellant load, lb	332.9	334.7	337.2	335.8
Helium service pressure, psia	4118	4075	4112	4164
Helium tank loading temperature, °F	71	72	70	73

TABLE V.- SERVICE MODULE RCS EVENT TIME LINE

Event	Time, g.e.t.
SM RCS activation	-00:28:40
Lift-off	00:00:00.7 (16:00:00.7 G.m.t.)
CSM/LM S-IVB separation command	[a]2:41:16
CSM/LM S-IVB docking	3:01:59.3
CSM/LM ejection from S-IVB	[a]4:08:06
SPS-4 ullage burn	28:24:23.5
SPS-5 ullage burn	54:26:01.5
LM/CSM undocking	92:39:36
LM/CSM separation maneuver	[a]93:02:54
LM/CSM docking	99:02:26
SPS-6 ullage burn	123:24:49.6
SPS-7 ullage burn	169:38:42.4
SPS-8 ullage burn (deorbit)	240:30:58.2
CSM separation	240:36:03.8

[a]Times not verified by bilevel data.

TABLE VI.- SERVICE MODULE RCS ΔV PERFORMANCE

Ullage burn	Time, g.e.t.	Control authority	Burn duration, sec	Spacecraft weight, lb	ΔV on time, ft/sec	ΔV PIPA, ft/sec
SPS-4	28:24:23.5	4 engine — G&N	19.860	64 541	3.57	3.04
SPS-5[a]	54:26:01	4 engine — G&N	19.274	52 376	4.44	3.88
SPS-6	123:24:49.6	2 engine — G&N	19.364	27 000	4.04	3.76
SPS-7	169:38:42.4	2 engine — G&N	20.024	26 800	5.04	4.90
SPS-8	240:30:58.2	2 engine — G&N	18.695	24 900	4.61	5.08

[a]All values approximate due to noisy data at start of burn.

TABLE VII.- SERVICE MODULE RCS ATTITUDE CONTROL PERFORMANCE - PART I

Maneuver	Time, g.e.t.	Spacecraft weight, lb	Pitch acceleration, deg/sec^2	Yaw acceleration, deg/sec^2	Roll acceleration, deg/sec^2
+X	2:56:00	58 900			
	28:24:22	32 500			
	101:26:39	27 300	-0.41		
	101:27:10	27 300	-.31		
	101:27:25	27 300	-.31		
	101:28:10	27 300	-.27		
+Y	2:55:27	58 900		0.20	0.22
	2:55:43	58 900		.30	.24
	101:27:14	27 300		-.28	.61
-Y	101:28:10	27 300		.30	-.46
-Z	2:56:01	58 900	-.21		
	101:27:35	27 300	-.26		
	101:28:26	27 300	-.40		
+Pitch	2:51:58	58 900	1.17		
	2:53:34	58 900	1.21		
	2:56:46	58 900	1.10		
	92:41:36	27 000	1.62	-.42	
	92:41:41	27 000	1.59	-.26	
	101:26:21	27 300	1.76		
	101:27:42	27 300	1.76		
	101:29:12	27 300	1.81		
	240:32:40	24 900	1.78		
-Pitch	2:53:34	58 900	-.83		
	2:56:46	58 900	-.92		
	92:41:45	27 000	-1.35	.34	
	92:41:47	27 000	-1.45	.21	
	92:41:48	27 000	-1.35	.17	
	101:26:28	27 300	-1.45		
	101:27:51	27 300	-1.62	.23	

TABLE VII.- SERVICE MODULE RCS ATTITUDE CONTROL PERFORMANCE - PART II

Maneuver	Time, g.e.t.	Spacecraft weight, lb	Pitch acceleration, deg/sec^2	Yaw acceleration, deg/sec^2	Roll acceleration, deg/sec^2
+Yaw	2:53:31	58 900		0.87	
	2:53:33	58 900		.94	
	2:53:48	58 900		.97	
	2:56:44	58 900		.93	
	101:26:43	27 300		1.75	
	101:29:10	27 300		1.61	
-Yaw	2:53:18	58 900		-.97	
	2:53:32	58 900		-.98	
	2:53:49	58 900		-.76	
	2:55:23	58 900		-1.00	
	2:56:44	58 900		-.97	
	54:27:18	52 400		[a]-.29	
	101:26:12	27 300	-0.23	-1.75	
	123:25:12	27 000		-1.64	
	123:25:16	27 000		-1.70	
	169:39:30	26 800		-1.76	
	240:32:40	24 900		-2.36	
+Roll 2 engine	2:53:34	58 900			2.52
	25:21:35	32 500			2.01
-Roll 2 engine	2:53:34	58 900			-2.12
	25:21:36	32 500			-2.18
+Roll 4 engine	2:54:19	58 900			5.59
	240:32:40	24 900			11.16
-Roll 4 engine	2:54:40	58 900			-4.20

[a]During CSM/LM docked configuration.

TABLE VIII.- SELECTED PREFLIGHT CHECKOUT DATA, SM RCS HELIUM PRESSURIZATION SYSTEM

(a) Helium pressure regulators

Parameter	Specification value	Quad A		Quad B		Quad C		Quad D	
		Assy 1	Assy 2	Assy 1	Assy 2	Assy 1	Assy 2	Assy 1	Assy 2
Primary regulation, psia	181 ± 4	180	182	180	180.5	180.5	179	181	180
Primary lockup, psia	183 ± 5	183	183.5	182	182	182	181.5	183	181
Secondary regulation, psia . . .	185 ± 4	184	185	184.5	183	185	183	184	184
Secondary lockup, psia	187 ± 5	185.5	186.5	186.5	185	187.5	185.5	186	186

(b) Relief valves

Parameter	Specification value	Quad A		Quad B		Quad C		Quad D	
		Fuel	Oxid	Fuel	Oxid	Fuel	Oxid	Fuel	Oxid
Cracking pressure, psia	225 to 248	237	240	238	235	236	238	237.5	238
Reseat pressure, psia	>220	228	228	233	228	226	230	228.5	233

TABLE IX.- SERVICE MODULE RCS TCS PARAMETERS

Quad	Heater S/N	Primary system			Secondary system		
		Volts	Watts (a)	Quad total watts (a)	Volts	Watts (a)	Quad total watts (a)
A	206 209	25.0 25.0	37.6 37.5	75.1	25.0 25.0	37.6 37.8	75.4
B	219 253	25.0 25.0	38.0 38.1	76.1	25.0 25.0	38.0 38.1	76.1
C	200 230	25.0 25.0	38.1 38.0	76.1	25.0 25.0	38.1 38.1	76.2
D	191 192	25.0 25.0	38.0 38.0	76.0	25.0 25.0	35.9 35.6	71.5

[a]Power based on heater operation at 25 V dc.

TABLE X.- COMPARISON OF VENDOR, NR-DOWNEY, AND KSC SM RCS TCS CHECKOUT DATA

Quad	Secondary switch limits, °F						Primary switch limits, °F					
	On			Off			On			Off		
	Vendor	NR	KSC	Vendor	NR	KSC	Vendor	NR	KSC	Vendor	NR	KSC
A	78	80	(a)	111	114	111	(b)	122	122	(b)	143.5	138
A	78	78	(a)	111	108	111	(b)	122	122	(b)	143.5	138
B	76	79	(a)	107	113	111	(b)	124	123	(b)	140	140
B	72	74	(a)	106	113	111	(b)	124	123	(b)	144	141
C	76	77	(a)	112	113	112	(b)	125	125	(b)	144	141
C	76	78	(a)	108	113	112	(b)	125	125	(b)	144	141
D	74	78	(a)	106	111	108	(b)	123	122	(b)	142	138
D	76	78	(a)	108	110	108	(b)	123	122	(b)	142	138

[a]Secondary thermostat "on" switching limits were not determined at KSC during the manned vacuum runs.

[b]Traceability of primary thermostats by serial number is not required. Therefore, the S/N's of the primary thermostats on each quad are not known and no acceptance data can be provided.

TABLE XI.- COMPARISON OF SM RCS TCS PRIMARY THERMOSTAT SWITCHING LIMITS DURING FLIGHT WITH PREFLIGHT CHECKOUT DATA

Quad	On, °F			Off, °F		
	NR	KSC	Flight	NR	KSC	Flight
A	122	122	119	143.5	138	136
B	124	123	121	140	140	139
C	125	125	123	144	141	141
D	123	122	121	142	138	136

TABLE XII.- COMPARISON OF GROUND-BASED PVT GAGING WITH ONBOARD P/T GAGING OF SM RCS PROPELLANT QUANTITY - PART I

Time, g.e.t.	PVT program, percent	Uncorrected P/T, percent	Corrected P/T, percent	Deviation PVT to P/T uncorrected, percent (a)	Deviation PVT to P/T corrected, percent (a)
Quad A					
10:39:49	80.4	81.2	76.1	+0.8	-4.3
50:00:21	74.2	76.4	71.6	+2.2	-2.6
89:42:54	70.3	73.3	69.5	+3.0	- .8
125:08:15	47.4	52.7	44.1	+5.3	-3.3
160:01:31	45.4	50.3	42.5	+4.9	-2.9
200:02:09	44.4	49.9	42.8	+5.5	-1.6
240:30:20	43.5	49.6	41.2	+6.1	-2.3
Quad B					
10:39:49	85.3	89.1	86.9	+3.8	+1.6
50:00:21	75.1	80.5	78.0	+5.4	+2.9
89:42:54	71.2	76.5	72.5	+5.3	+1.3
125:08:15	53.1	61.6	54.1	+8.5	+1.0
160:01:31	49.2	57.7	50.2	+8.5	+1.0
200:02:09	44.6	54.1	47.2	+9.5	+2.6
240:30:20	43.0	52.9	46.1	+9.9	+3.1

[a]The PVT value is regarded as zero deviation; any value above PVT is positive; any value below PVT is negative.

TABLE XII.- COMPARISON OF GROUND-BASED PVT GAGING WITH ONBOARD P/T GAGING OF SM RCS PROPELLANT QUANTITY - PART II

Time, g.e.t.	PVT program, percent	Uncorrected P/T, percent	Corrected P/T, percent	Deviation PVT to P/T uncorrected, percent (a)	Deviation PVT to P/T corrected, percent (a)
Quad C					
10:39:49	85.5	86.7	82.8	+1.2	-2.7
50:00:21	79.5	81.2	76.6	+1.7	-2.9
89:40:36	71.0	74.1	68.7	+3.1	-2.3
125:08:15	48.2	55.5	47.2	+7.3	-1.0
160:01:31	49.2	55.5	45.2	+6.3	-4.0
200:02:09	39.3	48.4	36.0	+9.1	-3.3
240:30:20	32.3	41.3	29.0	+9.0	-3.3
Quad D					
10:39:49	85.0	89.6	86.3	+4.6	+1.3
50:00:21	73.6	80.7	76.6	+7.1	+3.0
89:40:36	66.2	73.1	67.9	+6.9	+1.7
125:08:15	46.8	57	49.8	+10.2	+3.0
160:01:31	46.5	57.5	49.8	+11.0	+3.3
200:02:09	39.5	52.2	43.8	+12.7	+4.3
240:30:20	36.8	49.4	41.1	+12.6	+4.3

[a]The PVT value is regarded as zero deviation; any value above PVT is positive; any value below PVT is negative.

TABLE XIII.- COMMAND MODULE RCS INSTRUMENTATION LIST

Measurement number	Parameter	Telemetry (a)	Cabin display	Response, S/S	Data range
CR0001P	Helium tank pressure, system 1	PCM+	Yes	1	0 to 5000 psia
CR0002P	Helium tank pressure, system 2	PCM+	Yes	1	0 to 5000 psia
CR0003T	Helium tank temperature, system 1	PCM	Yes	1	0 to 300° F
CR0004T	Helium tank temperature, system 2	PCM	Yes	1	0 to 300° F
CR0035P	Helium manifold pressure, system 1	PCM+	No	10	0 to 400 psia
CR0036P	Helium manifold pressure, system 2	PCM+	No	10	0 to 400 psia
CR0037P	Helium manifold pressure, system 1	No	Yes	10	0 to 400 psia
CR0038P	Helium manifold pressure, system 2	No	Yes	10	0 to 400 psia
CR2100T	Injector temperature, -P, system 1	No	Yes	-	-50 to +50° F
CR2103T	Injector temperature, -Y, system 1	No	Yes	-	-50 to +50° F
CR2110T	Injector temperature, -P, system 2	No	Yes	-	-50 to 50° F
CR2114T	Injector temperature, CCW, system 1	No	Yes	-	-50 to +50° F
CR2116T	Injector temperature, +Y, system 2	No	Yes	-	-50 to +50° F
CR2119T	Injector temperature, CW, system 2	No	Yes	-	-50 to +50° F
CR1020X	Prop iso[b] valve position, system 1	No	Yes	1	On/off event
CR1021X	Prop iso valve position, system 2	No	Yes	1	On/off event

[a]Measurements labeled PCM are available only during periods of high-bit-rate data transmission. Measurements labeled PCM+ are available during periods of high- or low-bit-rate data transmission.

[b]Propellant isolation.

TABLE XIV.- COMMAND MODULE RCS CAUTION AND WARNING SWITCH LIMITS

Measurement number	Parameter	Hi/Lo	Redline	CW limits	
				Spec., psia	Actual psia
CR0035P	Helium manifold pressure, system 1	Hi Lo	332 psia None	330 260	316.9 263.4
CR0036P	Helium manifold pressure, system 2	Hi Lo	332 psia None	330 260	319.6 266.1
CR0037P[a]	Helium manifold pressure, system 1	Hi Lo	332 psia None	330 260	322.5 269.8
CR0038P[a]	Helium manifold pressure, system 2	Hi Lo	332 psia None	330 260	320.5 266.4

[a]Onboard display measurement.

TABLE XV.- COMMAND MODULE RCS PROPELLANT AND HELIUM SERVICING DATA

Parameter	System 1	System 2
Fuel tank load, lb	44.2	44.2
Fuel loading temperature, °F	69	69
Oxidizer tank load, lb	78.3	78.3
Oxidizer loading temperature, °F	70	70
Loaded O/F ratio	1.77	1.77
Total propellant load, lb	122.5	122.5
Helium service pressure, psia	4125	4069
Helium tank loading temperature, °F	65	59

TABLE XVI.- COMMAND MODULE RCS EVENT TIME LINE

Event	Start
CM RCS system activation	239:59:42.5
CM-SM separation	240:36:03.8
CM RCS system 2 deactivated	240:36:18.3
CM RCS disabled	240:55:06.1
CM RCS depletion burn	240:56:26
Helium purge	240:57:36
Propellant isolation valves closed	240:58:17

TABLE XVII.- COMMAND MODULE RCS ATTITUDE CONTROL PERFORMANCE

Maneuver	Time, g.e.t.	Control authority	Measured accel, deg/sec^2	Theoretical accel, deg/sec^2
+Roll	240:47:38	1 engine	3.36	4.52
	240:48:46	1 engine	4.02	4.52
	240:49:10	1 engine	3.94	4.52
	240:51:55	1 engine	4.46	4.52
	240:52:50	1 engine	4.19	4.52
-Roll	240:47:22	1 engine	-4.03	-4.52
	240:48:33	1 engine	-4.10	-4.52
	240:49:18	1 engine	-4.19	-4.52
	240:51:45	1 engine	-4.19	-4.52
	240:53:01	1 engine	-4.19	-4.52

TABLE XVIII.- SELECTED PREFLIGHT CHECKOUT DATA, CM RCS HELIUM PRESSURIZATION SYSTEM

(a) Helium pressure regulators

Parameter	Specification value	System 1		System 2	
		Assy 1	Assy 2	Assy 1	Assy 2
Primary regulation, psia	291 ± 6	287	287	290	289
Primary lockup, psia	285 to 302	289	288	291	290
Secondary regulation, psia	285 to 302	290	290.5	291	289
Secondary lockup, psia	285 to 308	293	292	292	290

(b) Relief valves

Parameter	Specification value	System 1		System 2	
		Assy 1	Assy 2	Assy 1	Assy 2
Cracking pressure, psia	346 ± 14	345	343	352	351
Reseat pressure, psia	>327	341	338	340	338

TABLE XIX.- COMMAND MODULE RCS ENGINE FIRING SUMMARY

System	Engine	No. pulses	Total on time, sec
1	+P	67	1.985
1	-P	110	10.900
1	+Y	88	9.775
1	-Y	44	6.900
1	+R	64	21.145
1	-R	120	28.440
2	+P	1	0.200
2	-P	2	0.030
2	+Y	0	0.0
2	-Y	3	0.045
2	+R	0	0.0
2	-R	0	0.0
System 1 totals . . .		493	79.145
System 2 totals . . .		6	0.275
Overall totals . . .		499	79.420

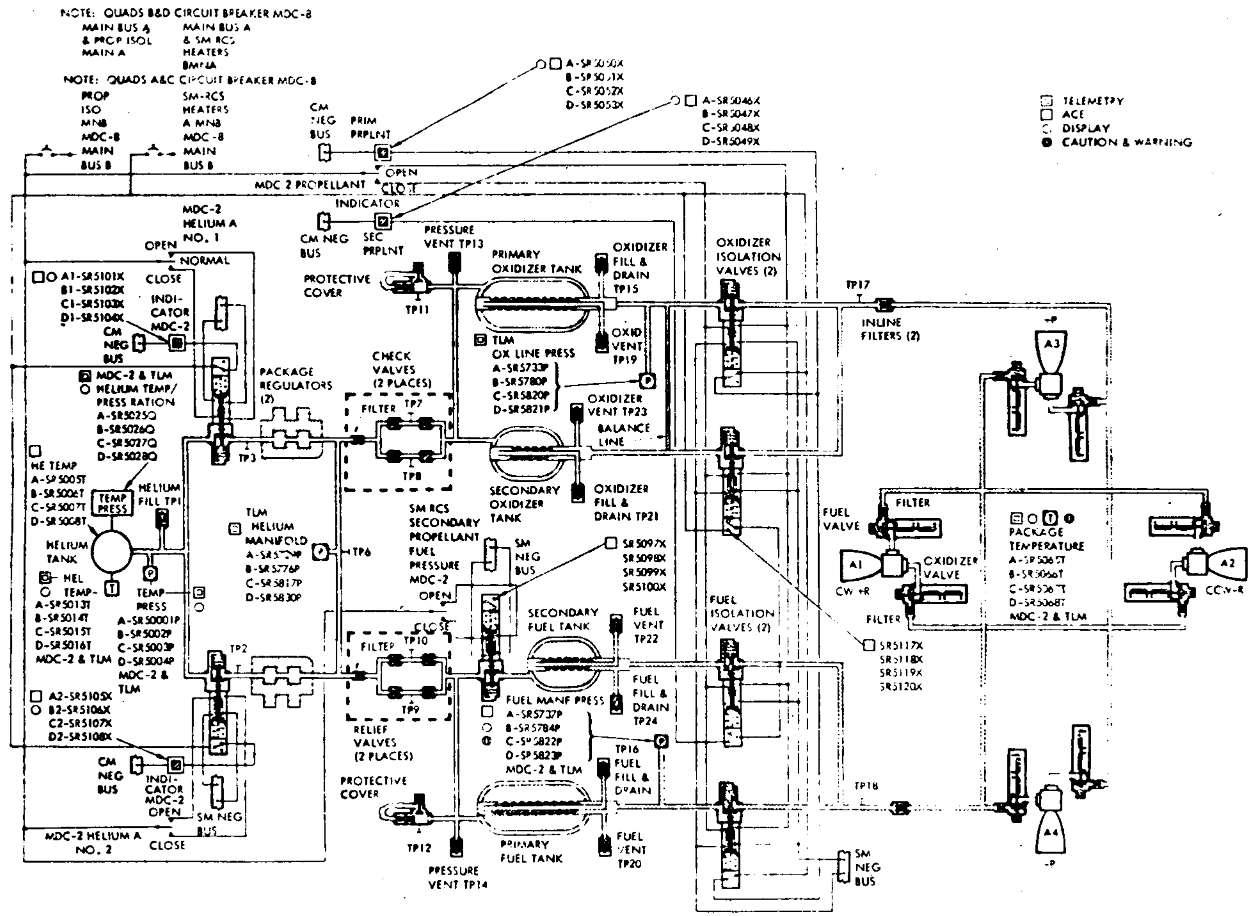


Figure 1.- Service module RCS schematic.

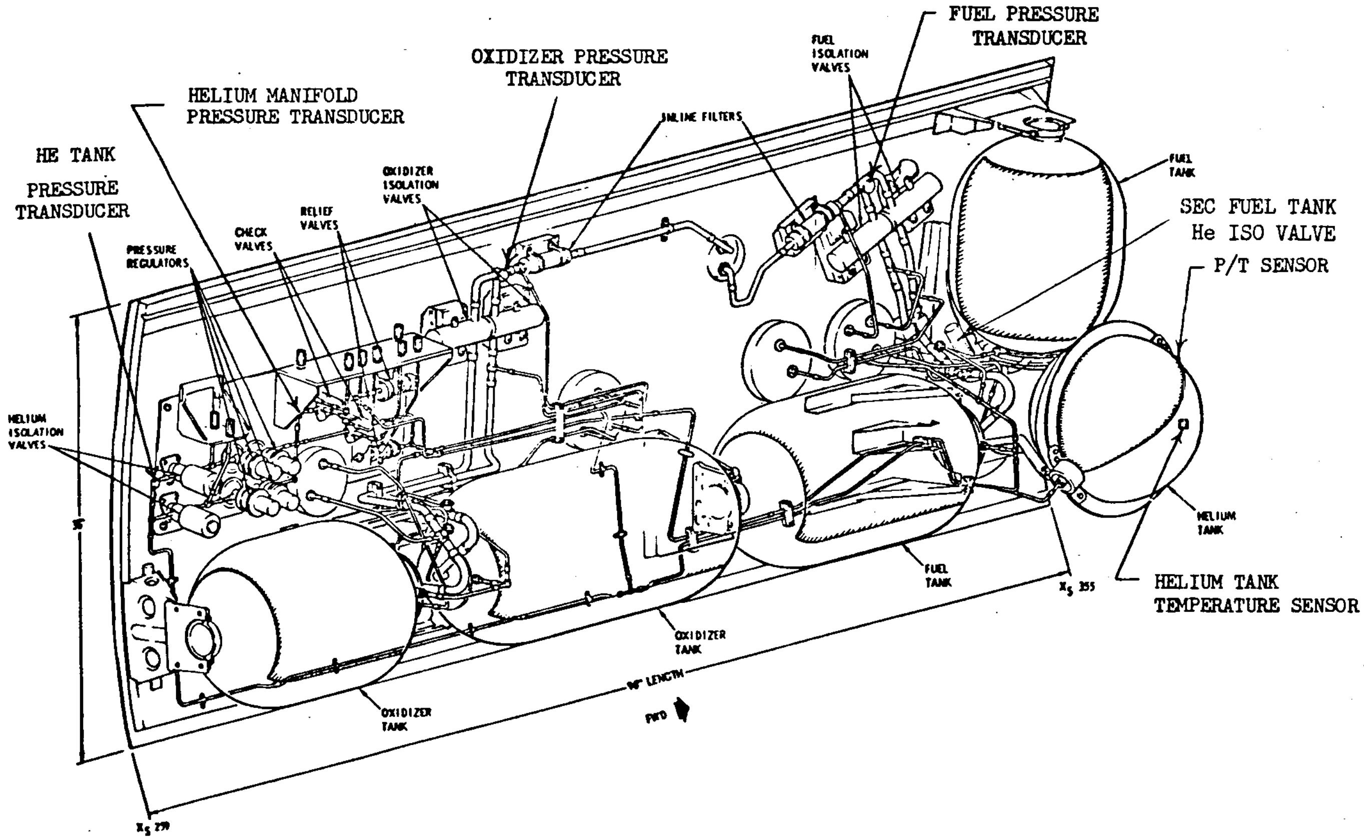
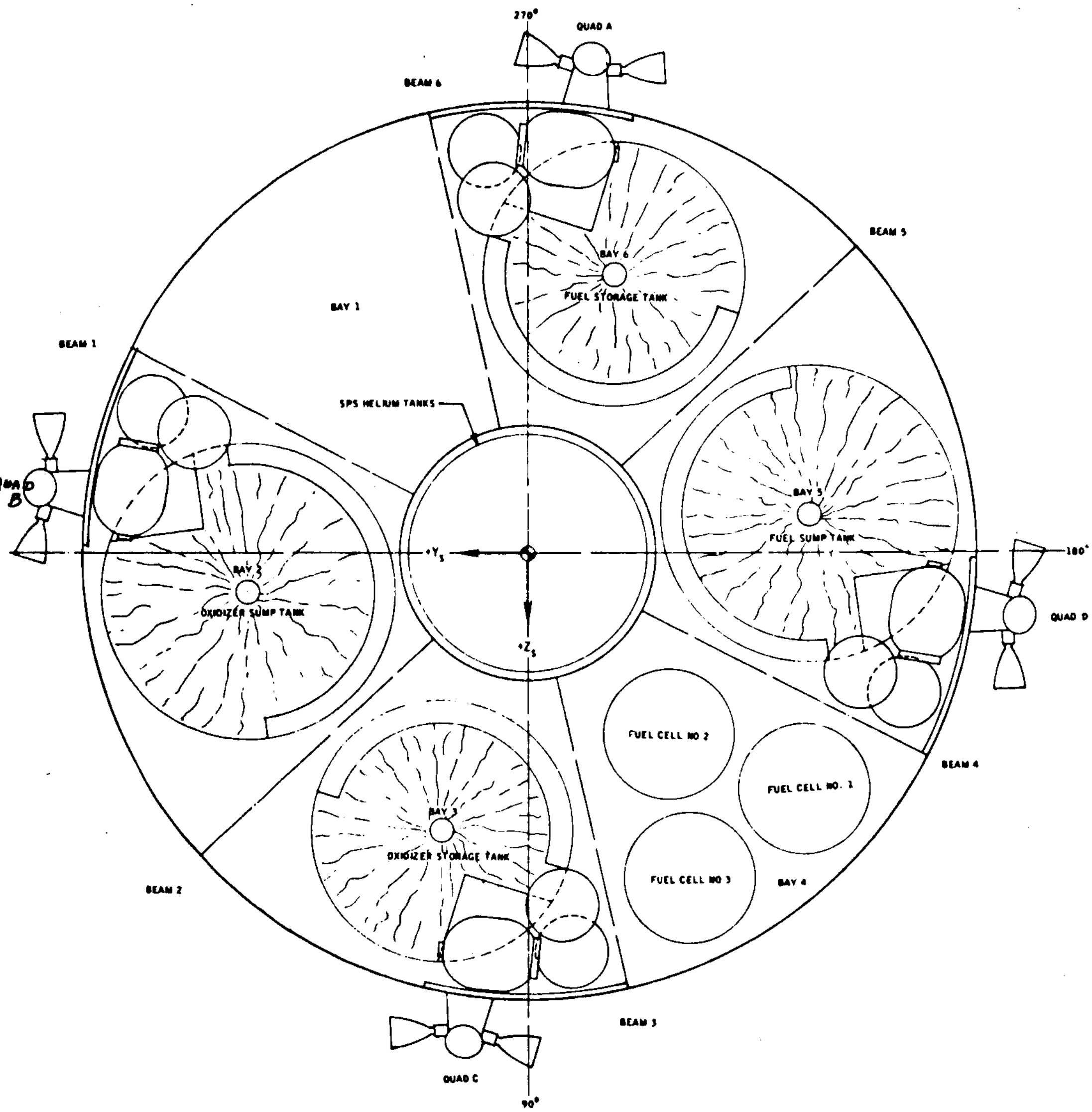
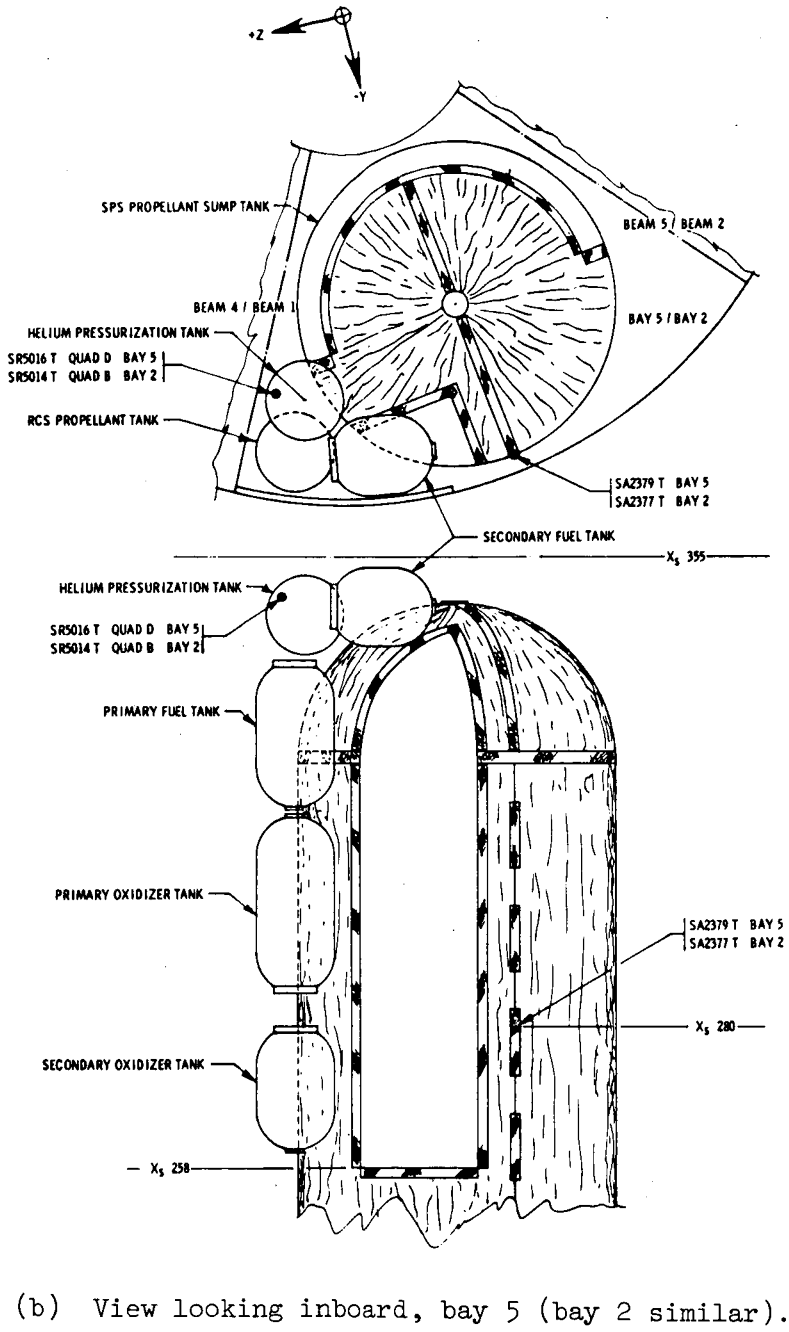


Figure 2.- Service module RCS panel assembly, quads B and D.



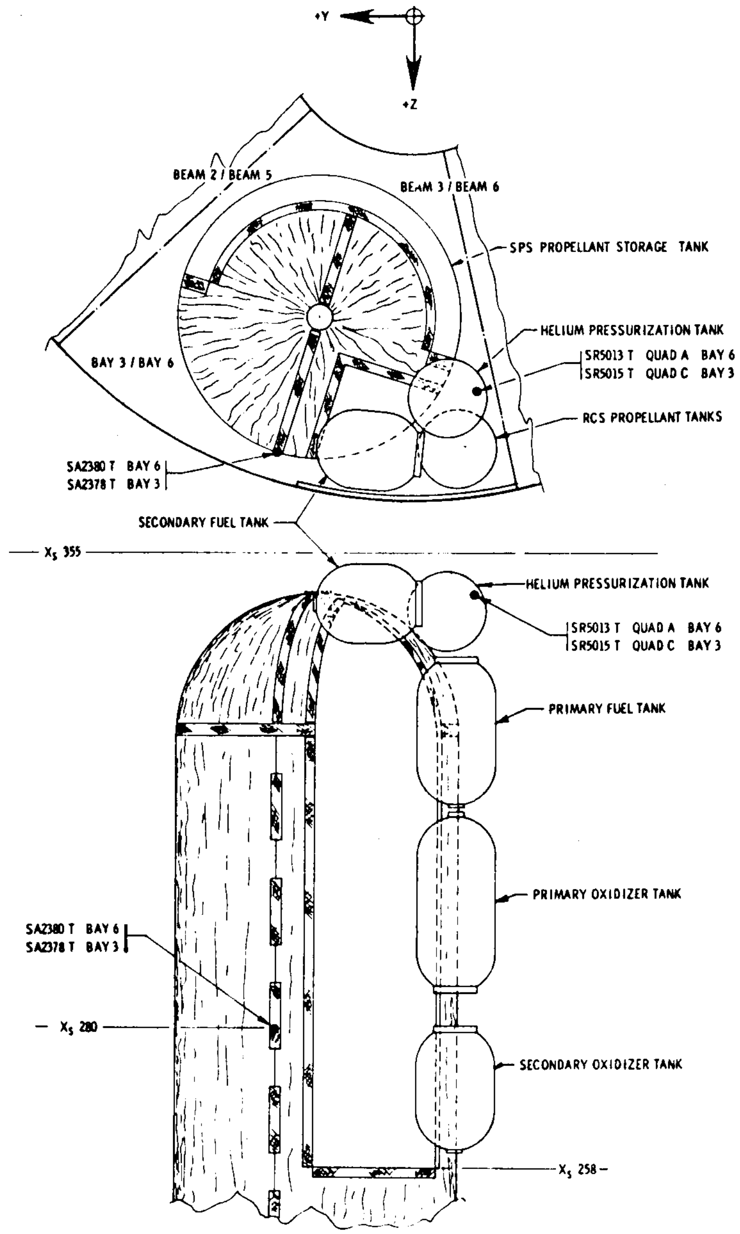
(a) View looking aft.

Figure 3.- Location of SM RCS components within the SM.



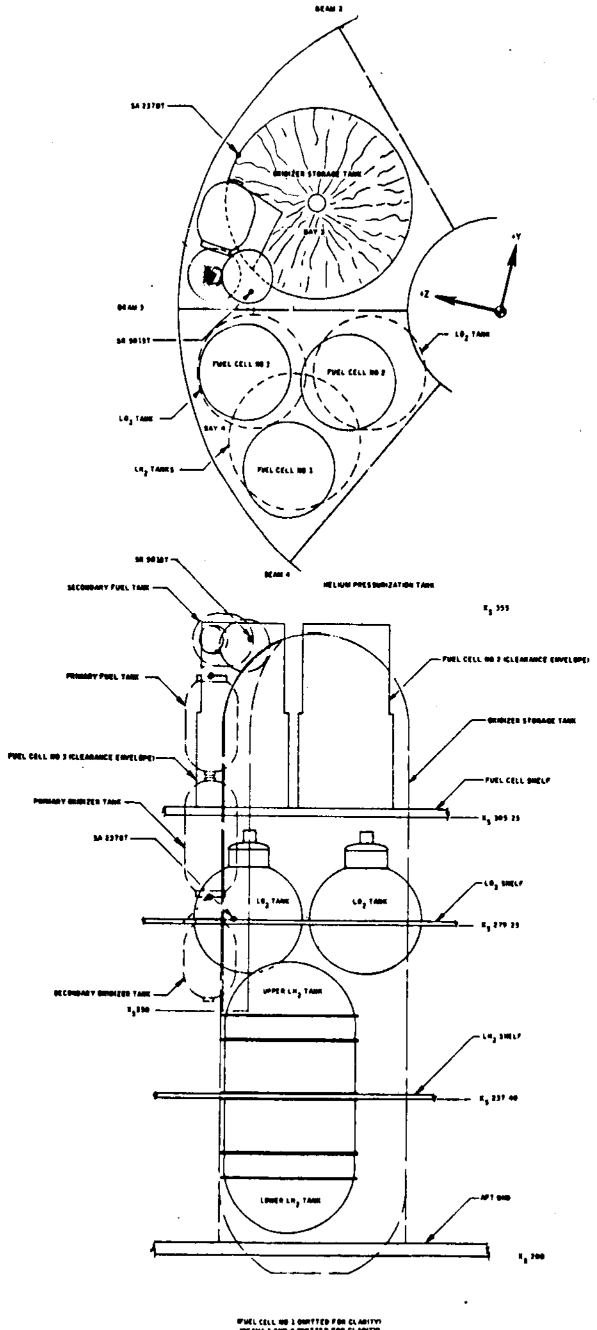
(b) View looking inboard, bay 5 (bay 2 similar).

Figure 3.- Continued.



(c) View looking inboard, bay 3 (bay 6 similar).

Figure 3.- Continued.



(d) View looking normal to beam 3.

Figure 3.- Concluded.

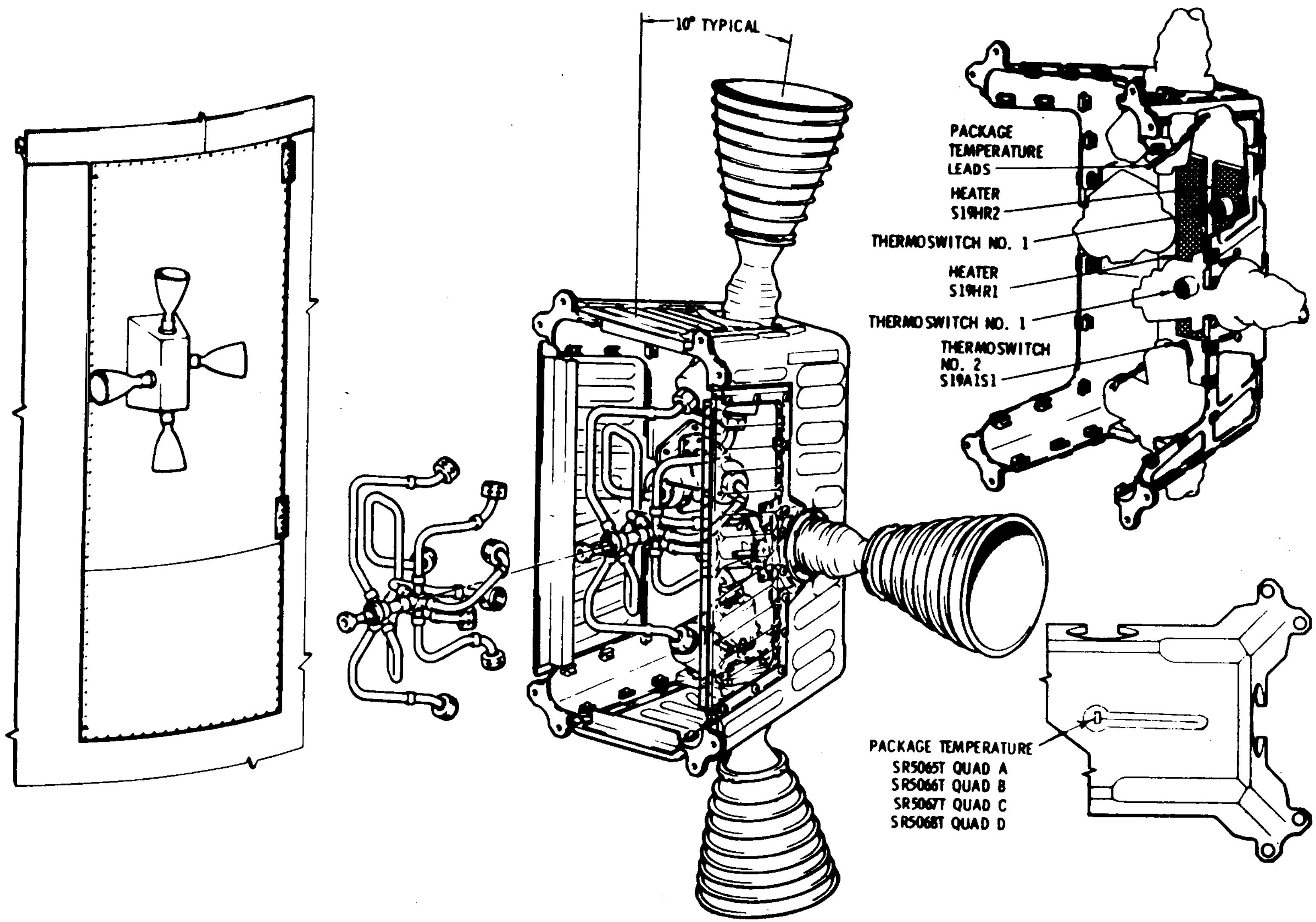


Figure 4.- Service module RCS quad engine housing.

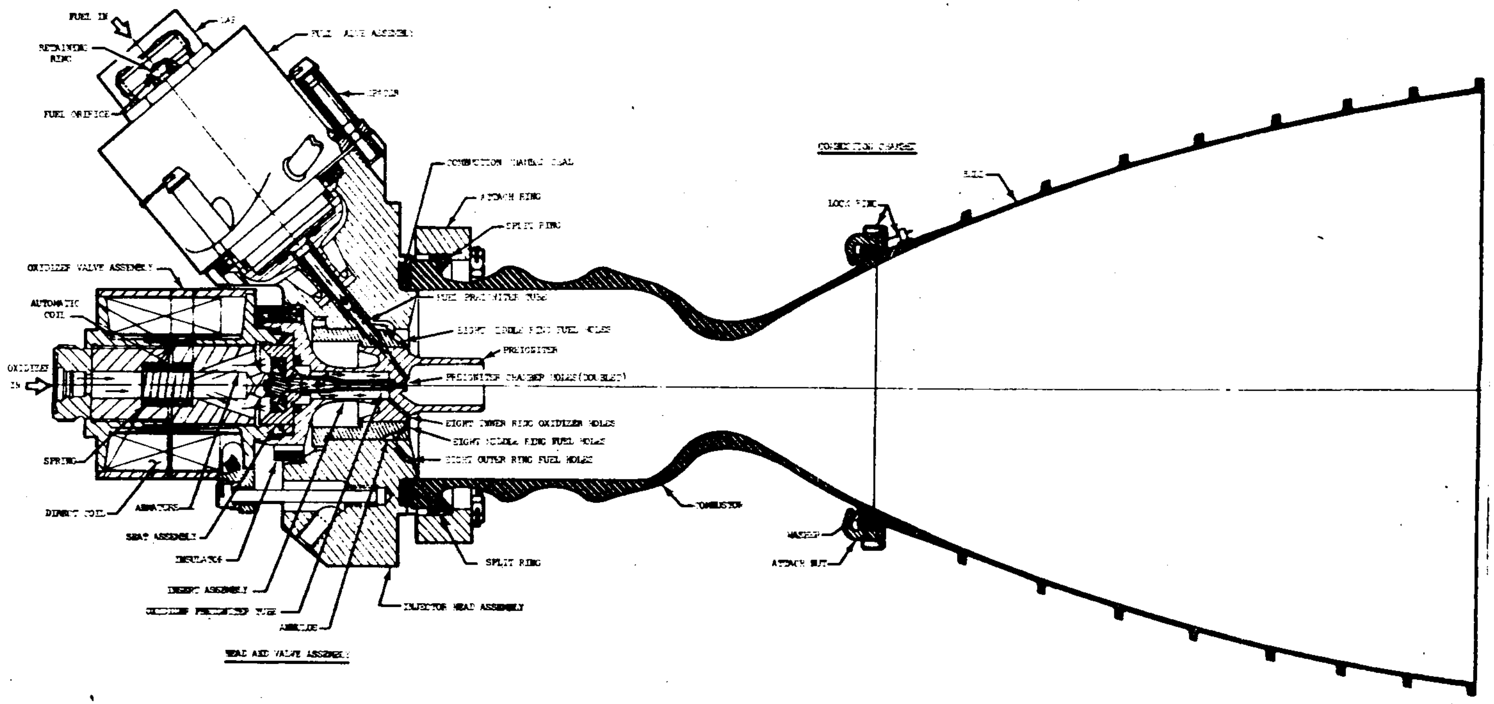


Figure 5.- Service module RCS engine.

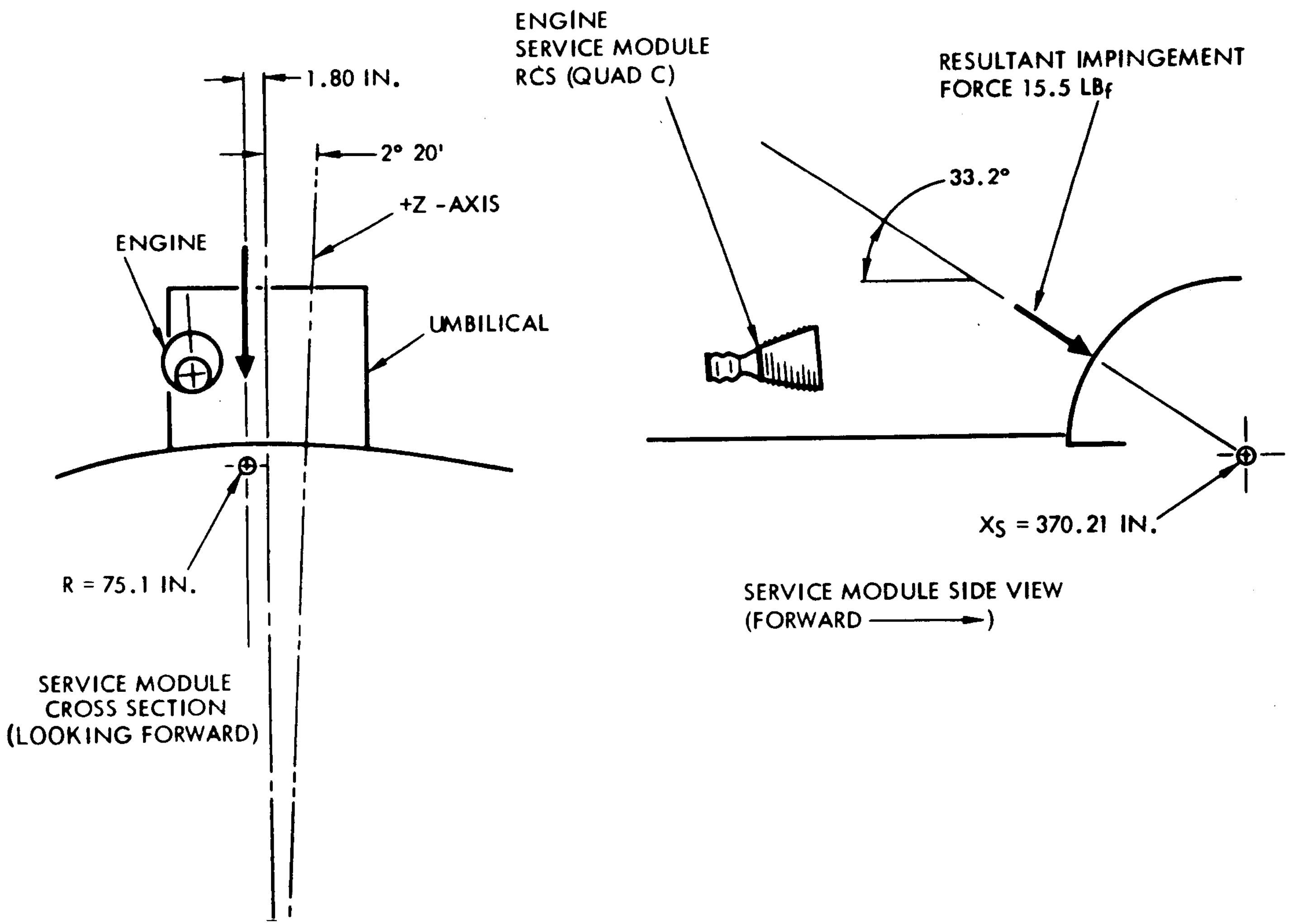


Figure 6.- Location of CSM umbilical relative to the forward firing (-x/-P) engine of SM RCS quad C.

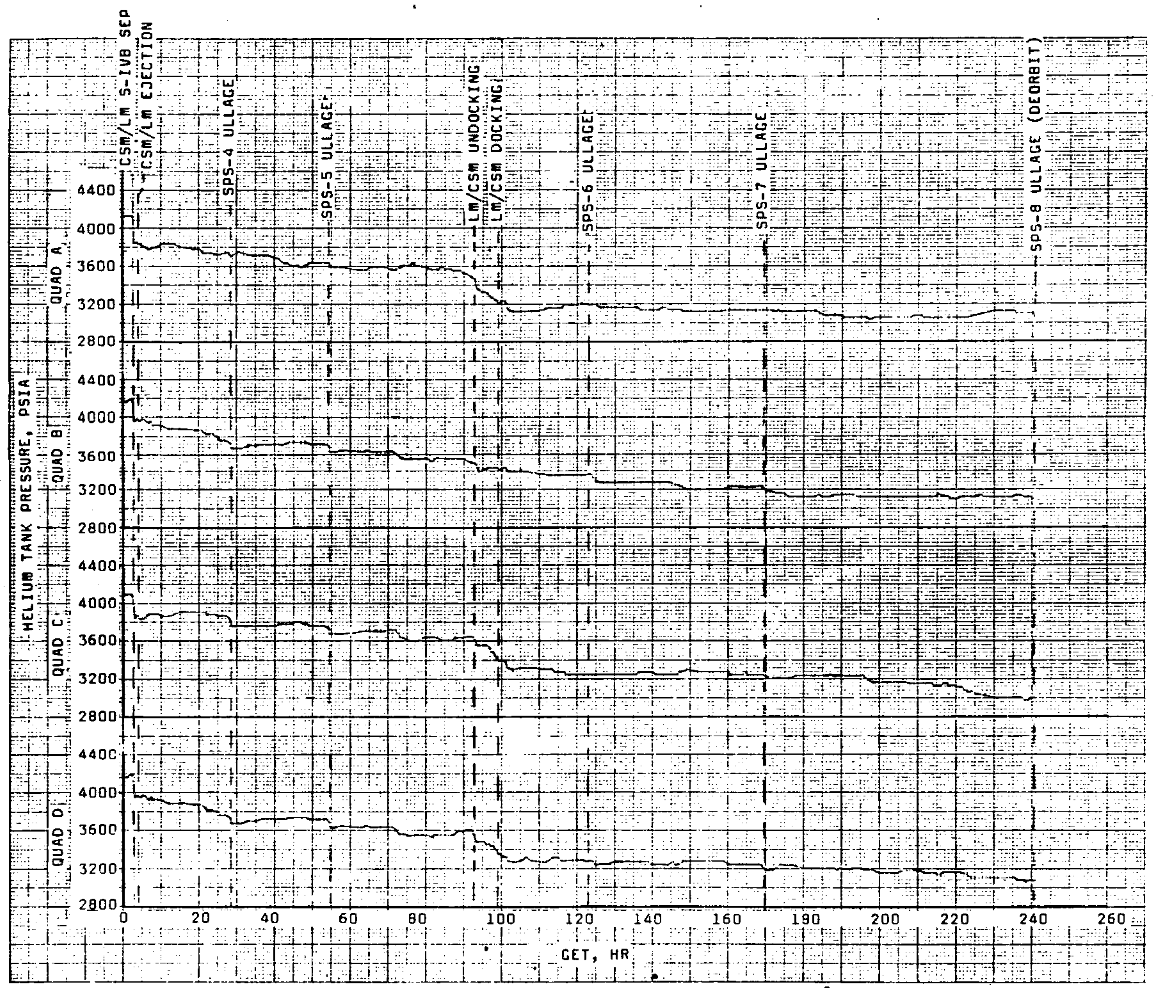


Figure 7.- Service module helium tank pressure as a function of time.

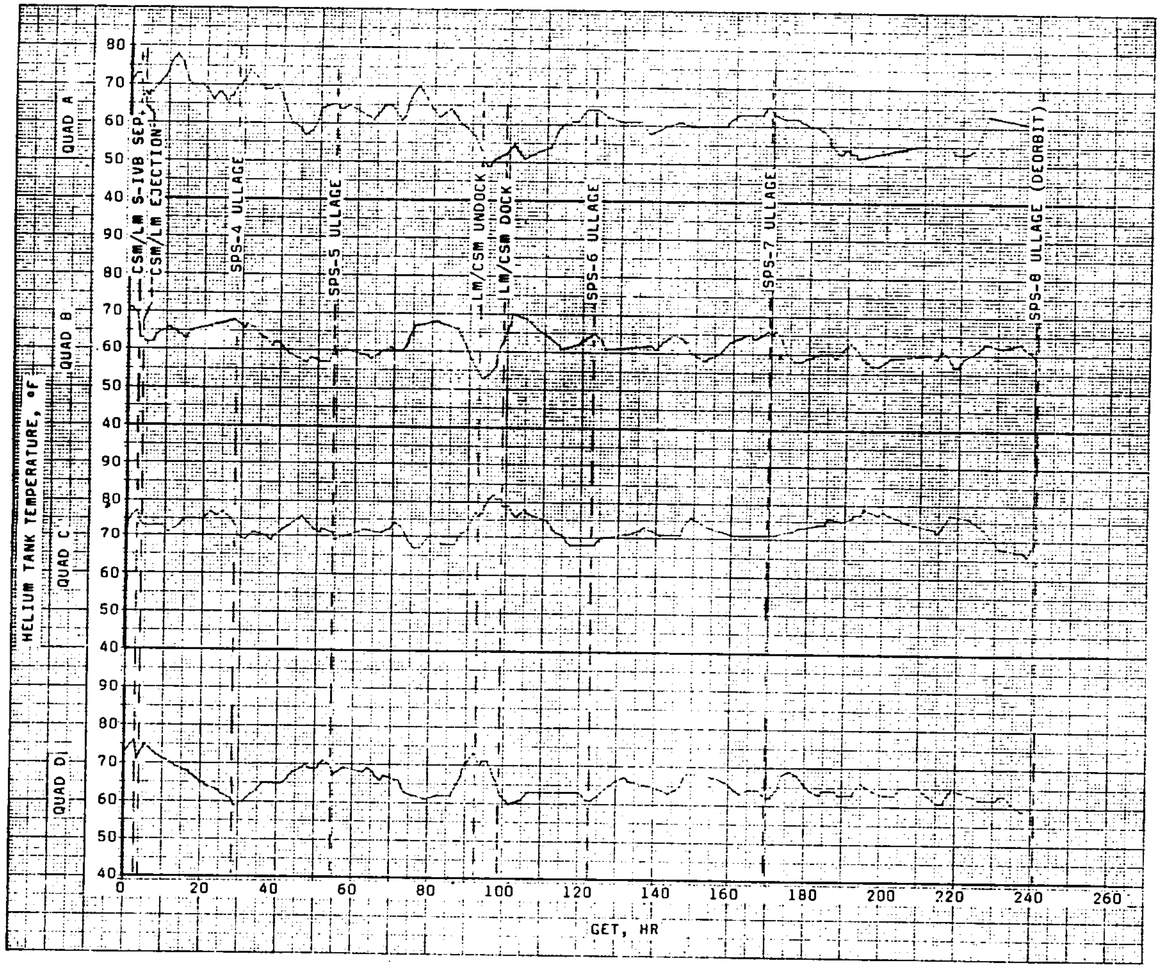
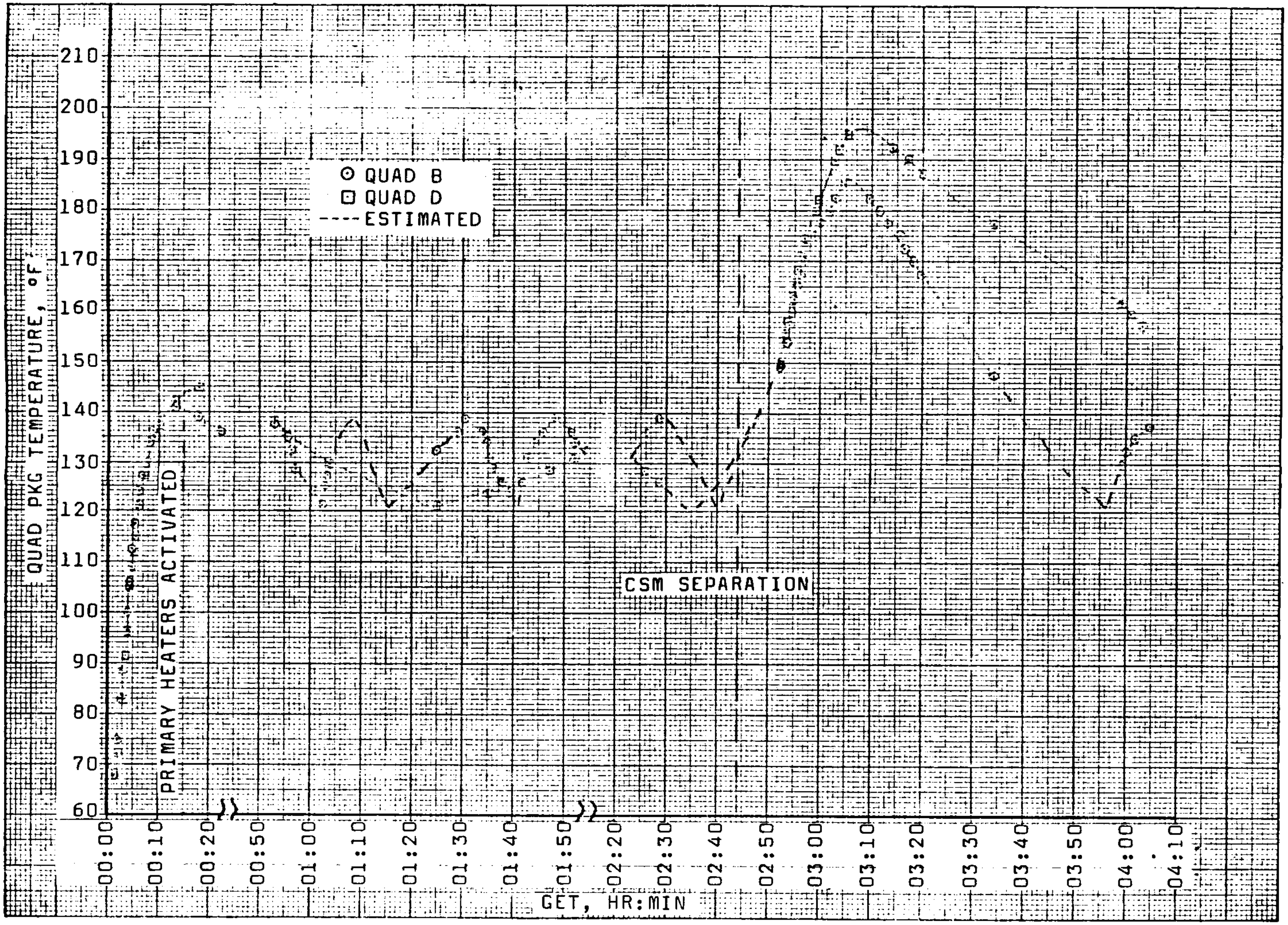
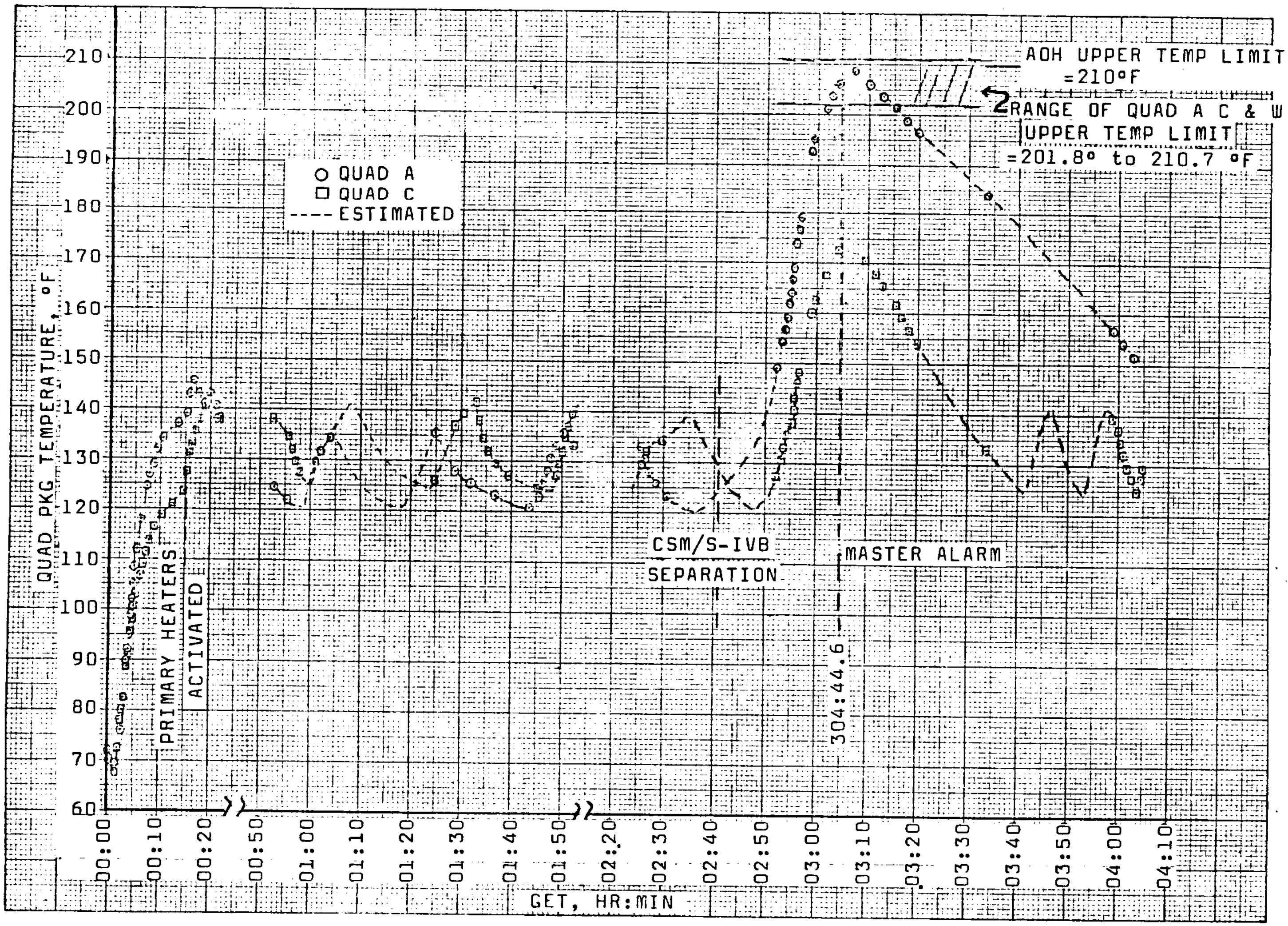


Figure 8.- Service module helium tank temperature as a function of time.



(a) Quads B and D.

Figure 9.- Comparison of quad package temperatures from launch through CSM-LM/S-IVB separation.



(b) Quads A and C.

Figure 9.- Concluded.

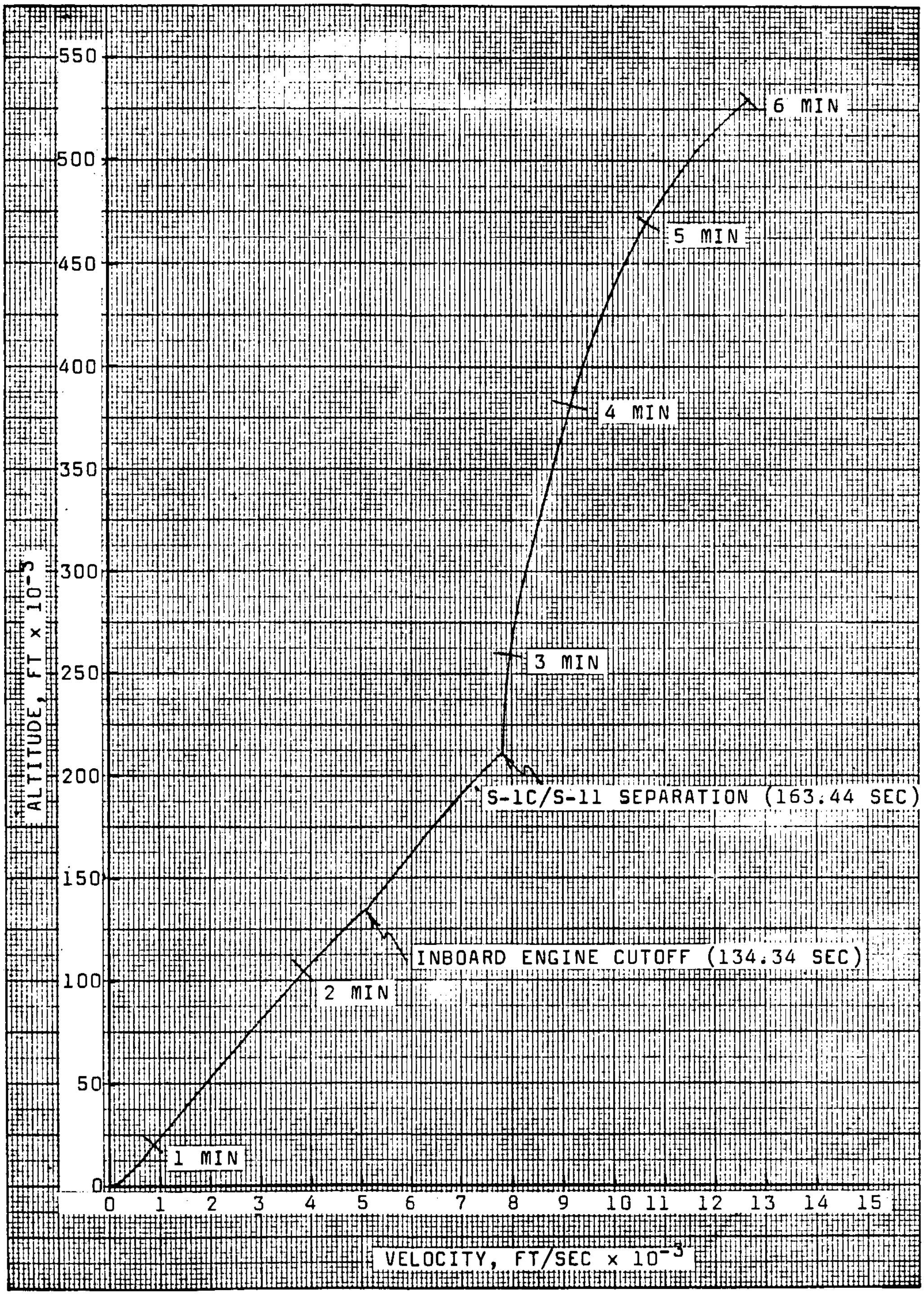
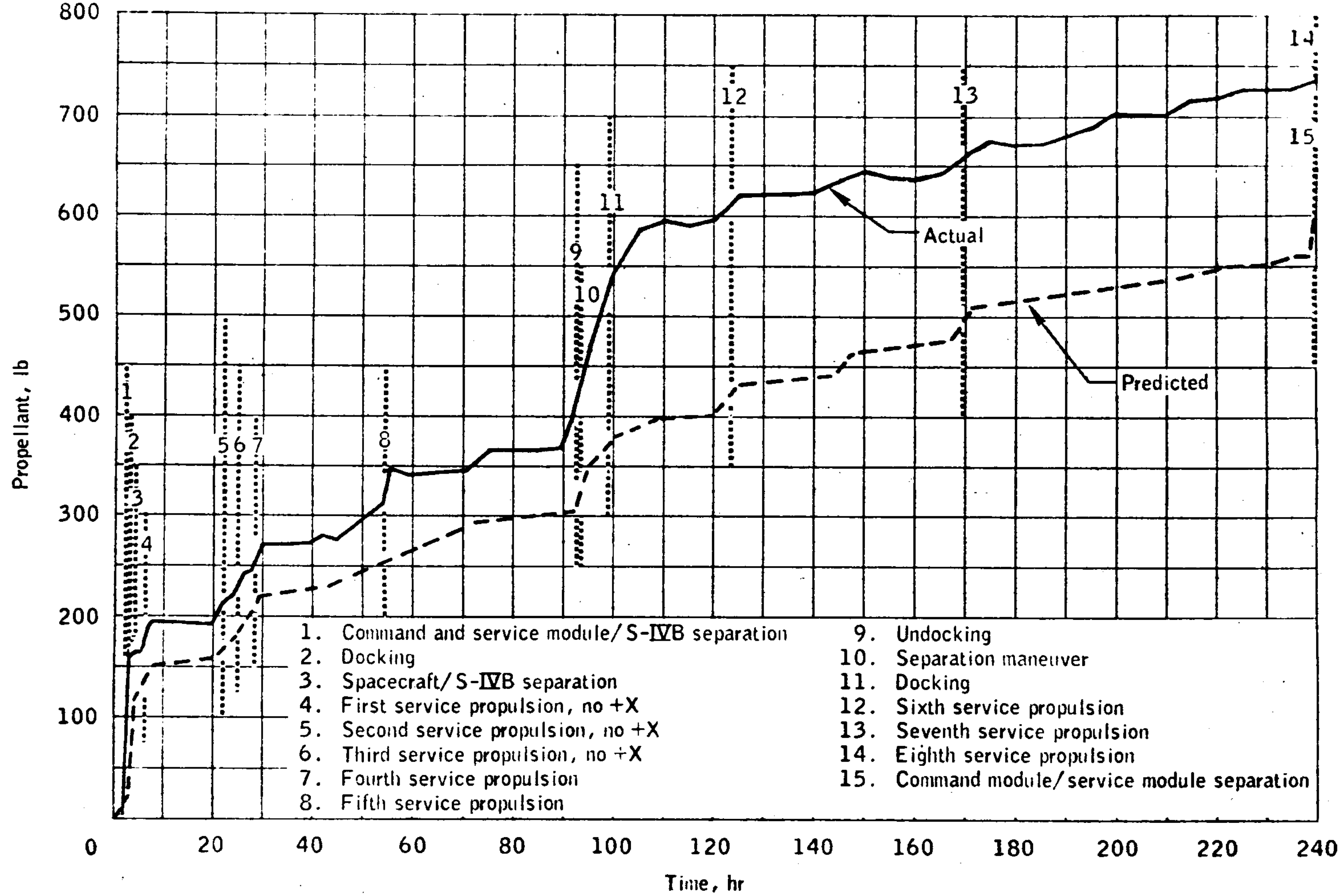
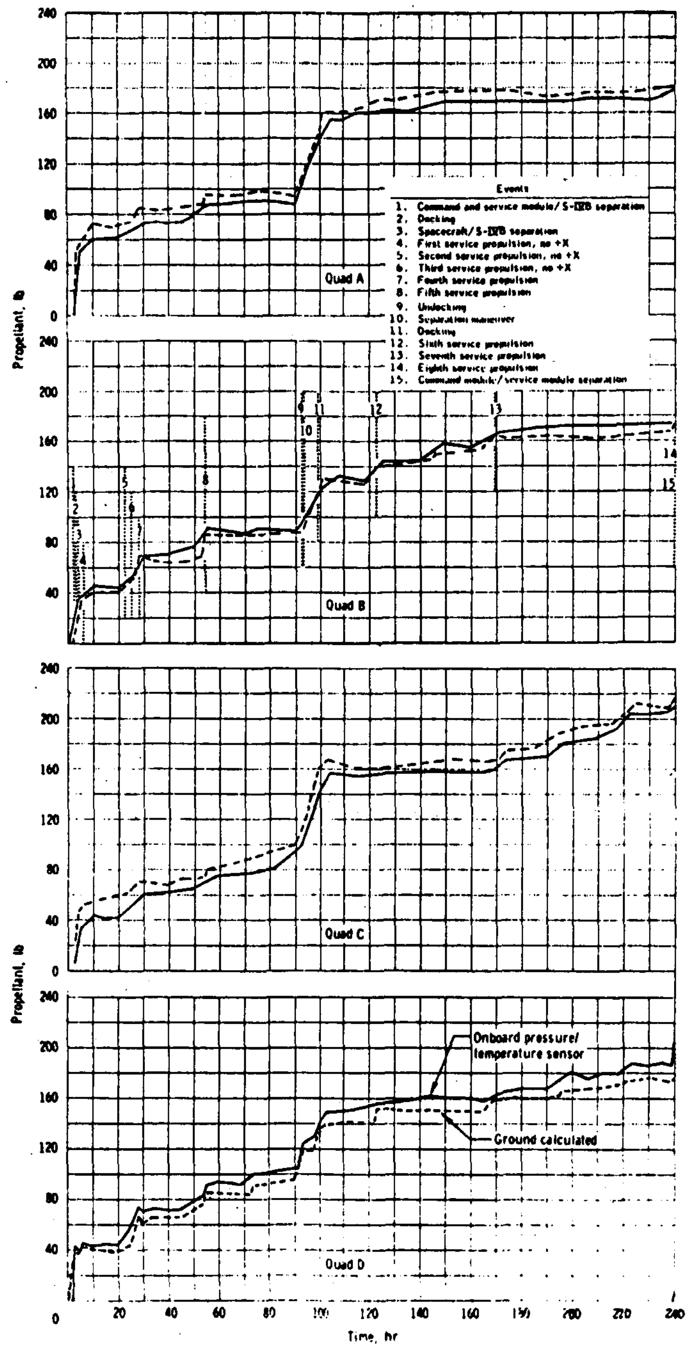


Figure 10.- Apollo 9 launch trajectory.



(a) Comparison of actual and predicted propellant consumption.

Figure 11.- Service module RCS propellant consumption profiles.



(b) Individual quad propellant consumption.

Figure 11.- Concluded.

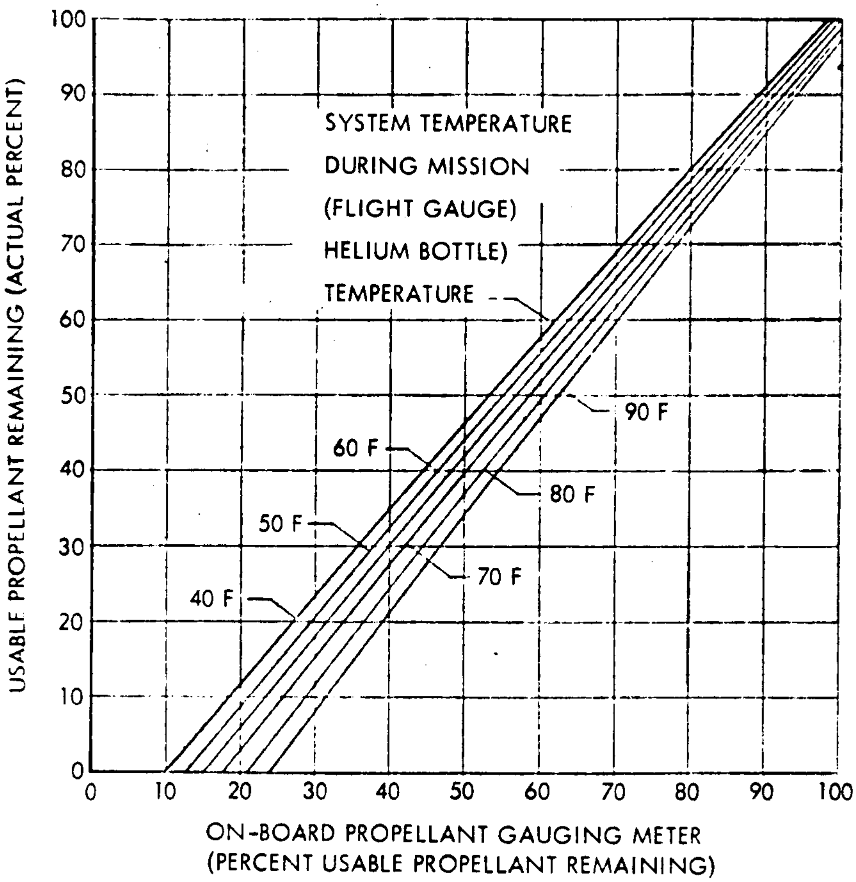


Figure 12.- Minus two-sigma SM RCS onboard propellant gaging meter correction nomogram.

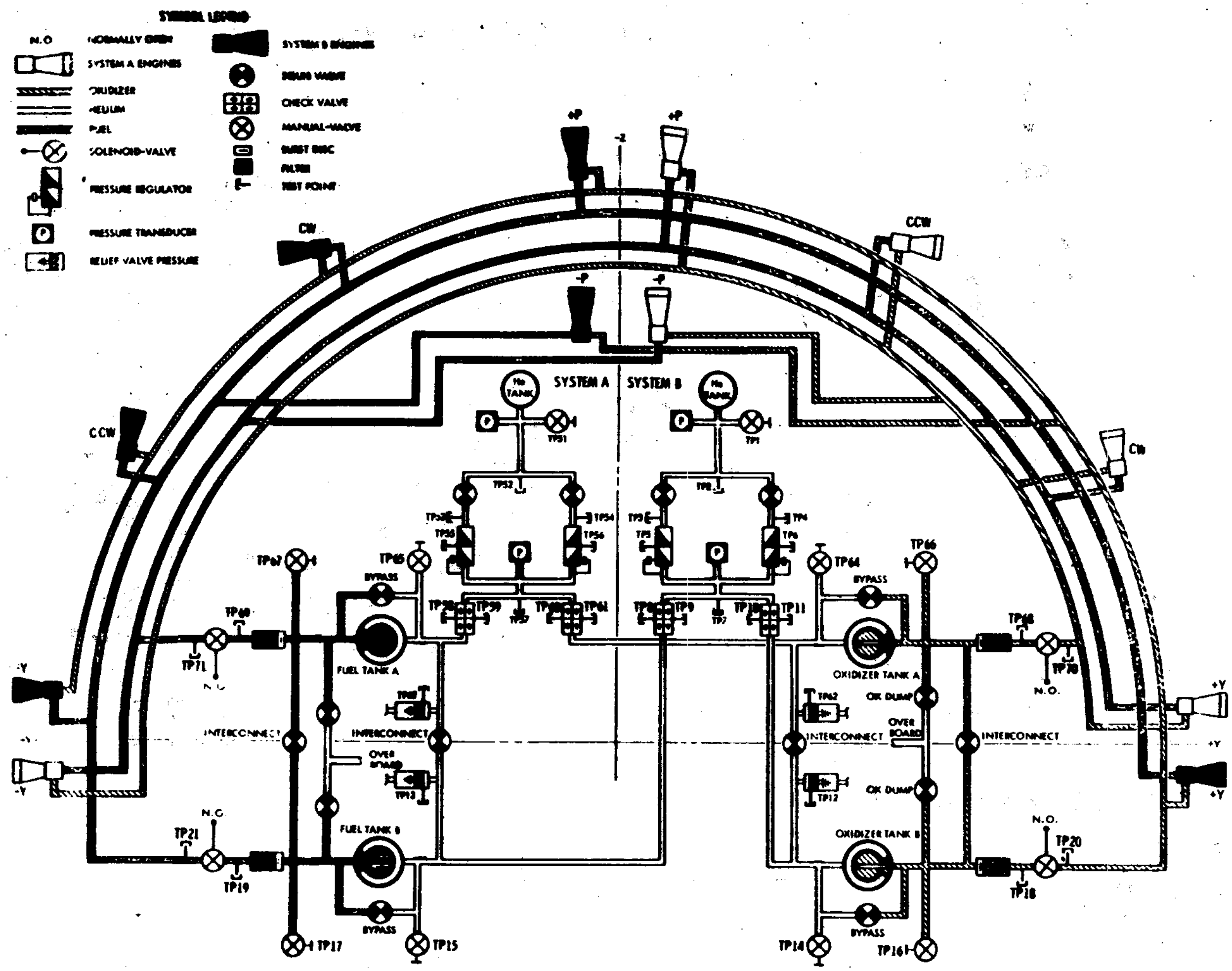


Figure 13.- Command module RCS flow schematic.

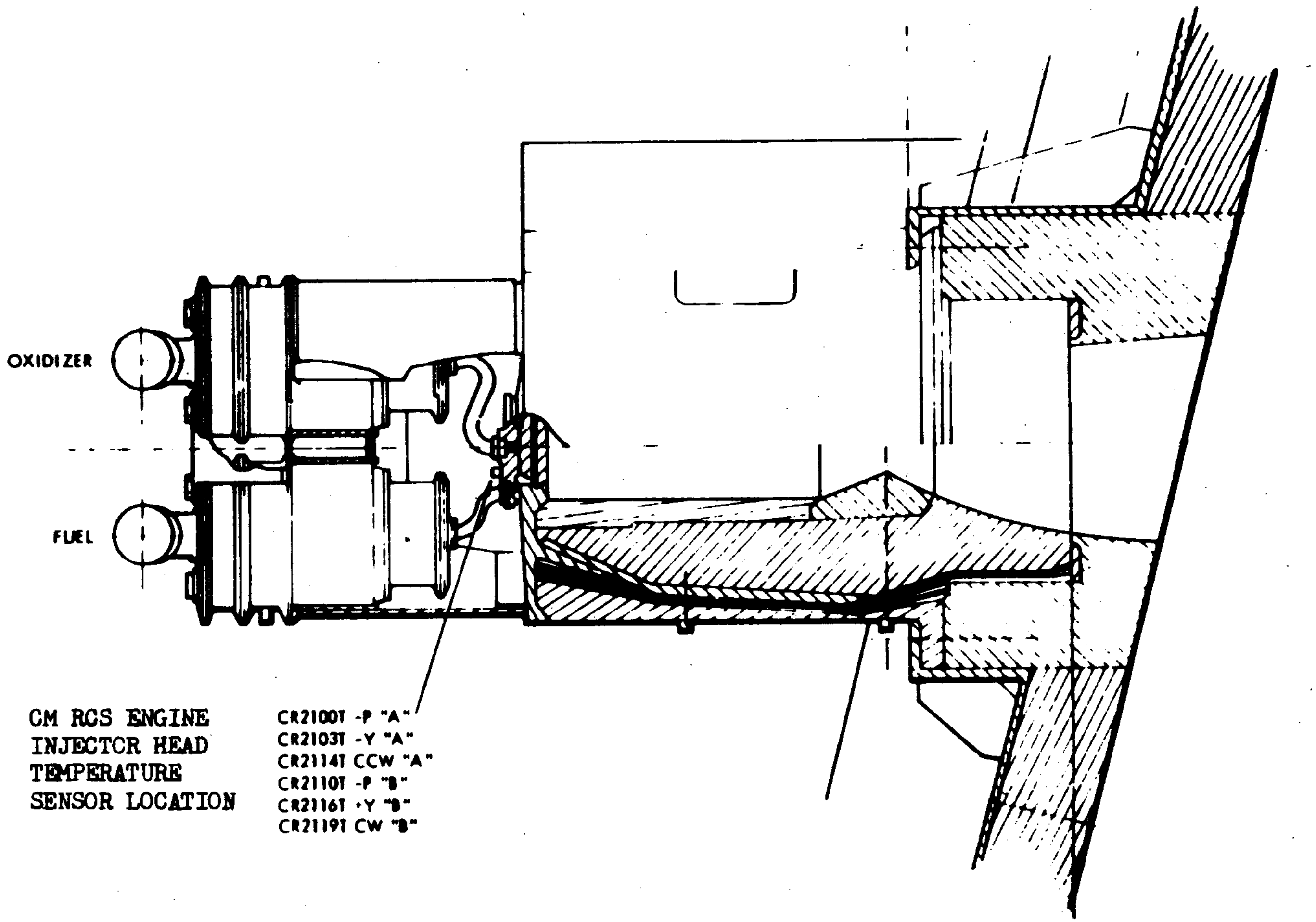


Figure 14.- Typical CM RCS engine.

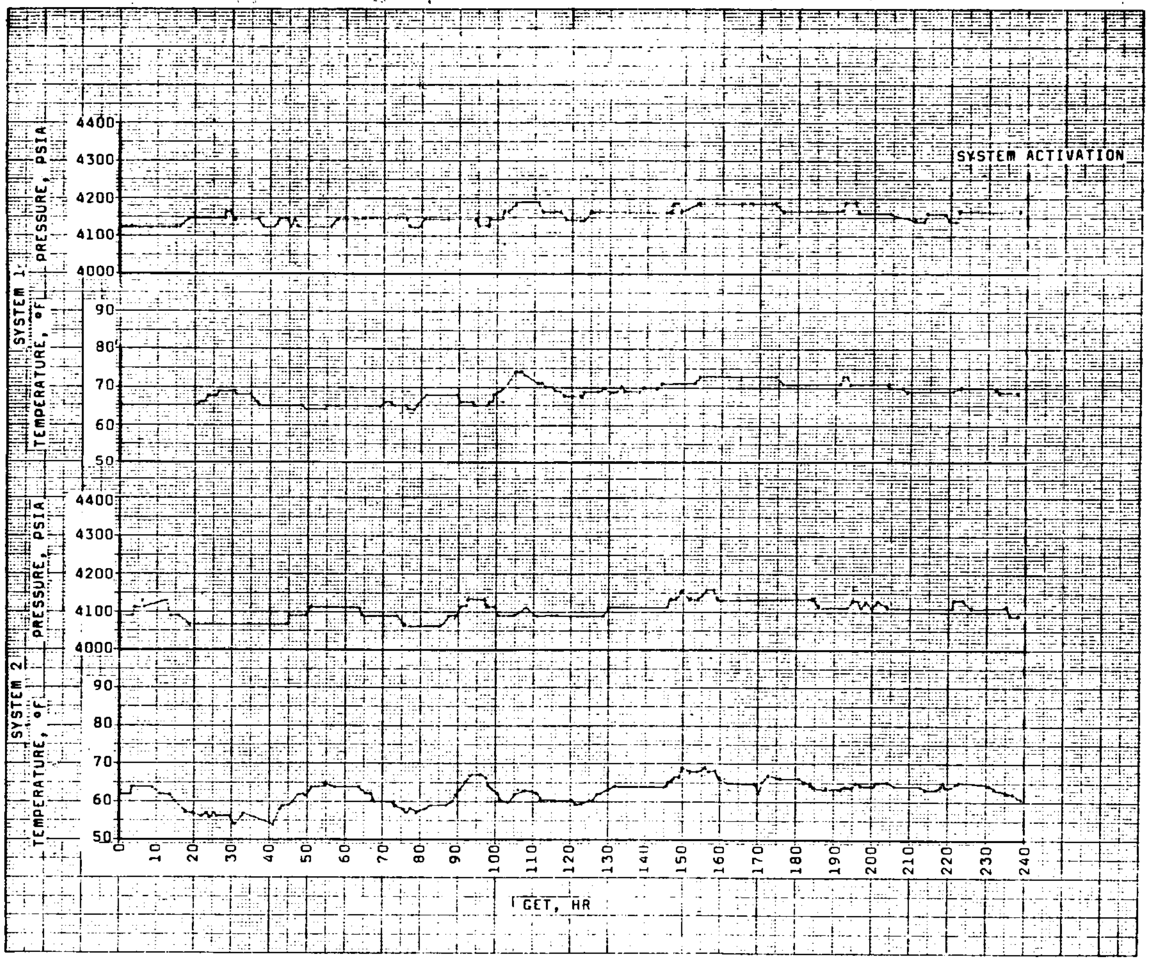


Figure 15.- Command module RCS helium tank pressure and temperature from launch to system activation.

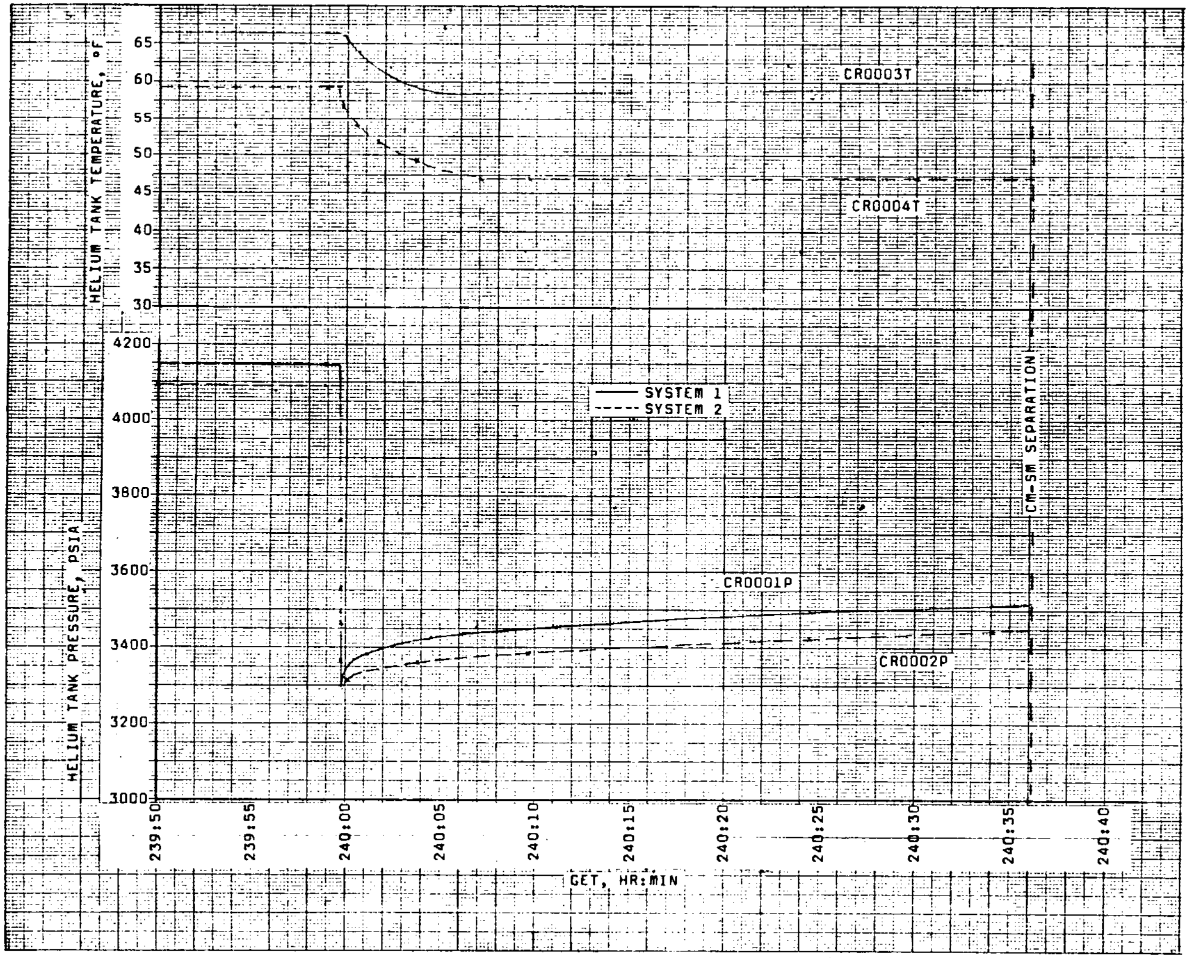
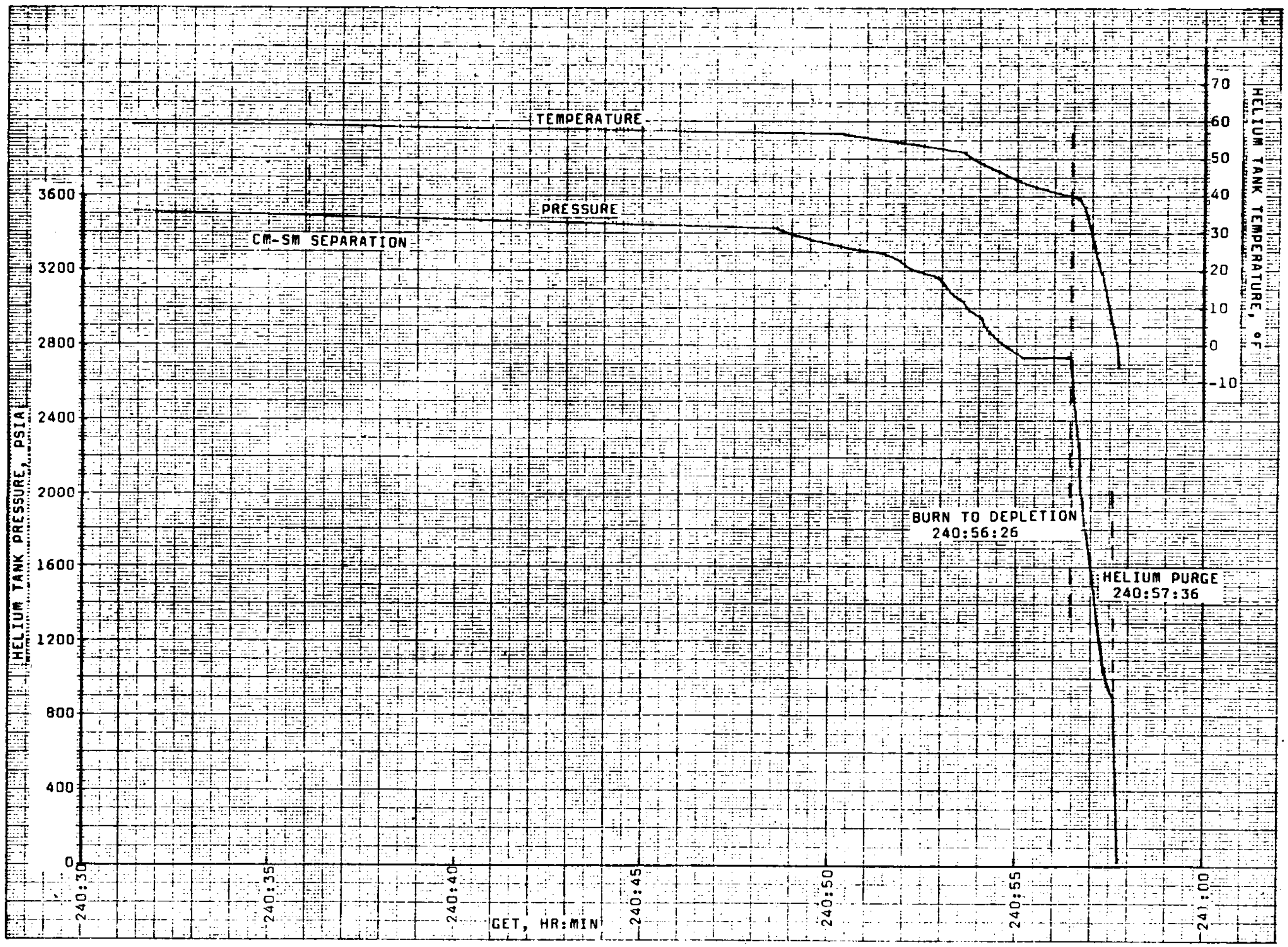
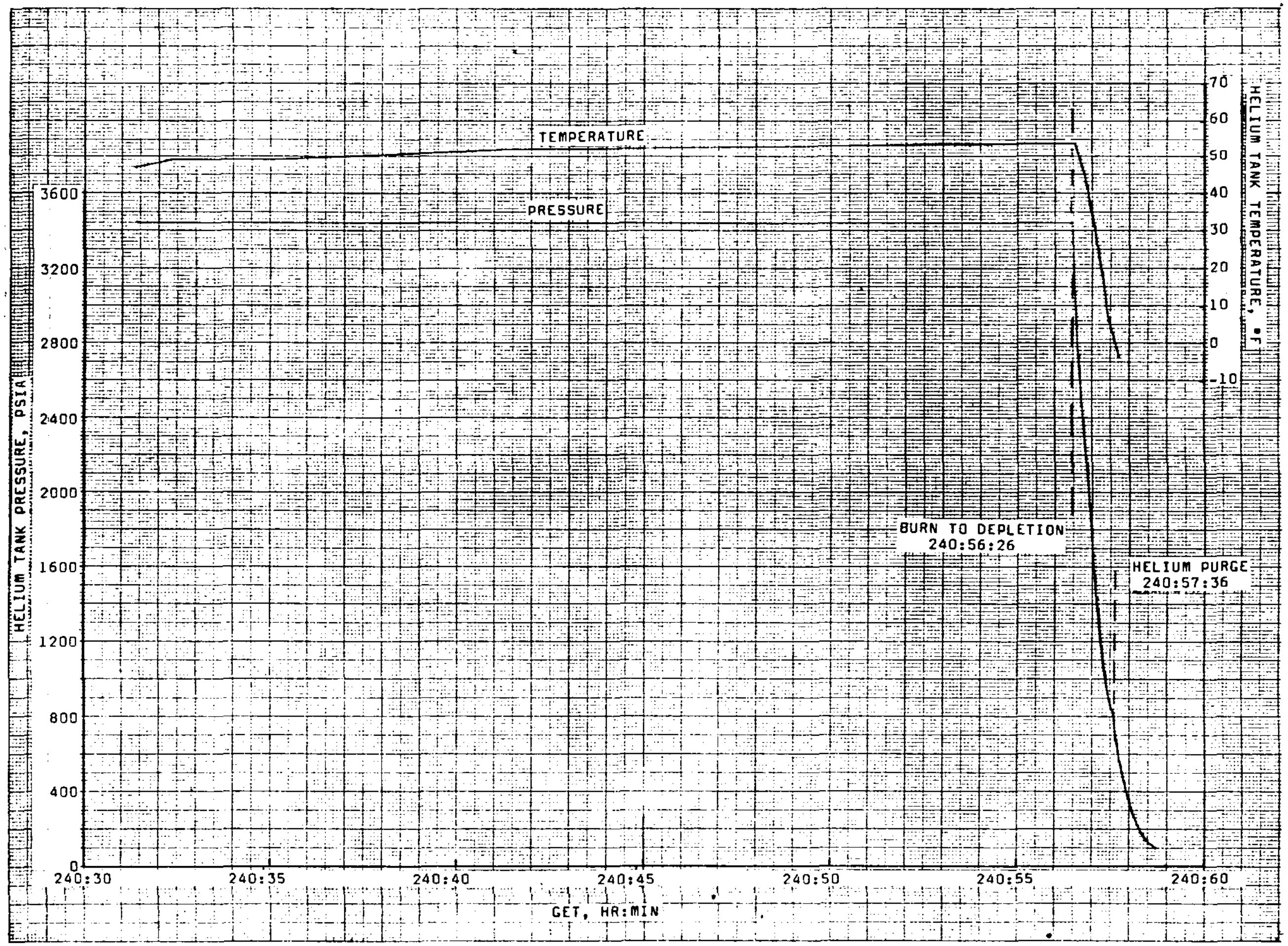


Figure 16.- Command module RCS helium tank pressure and temperature from system activation to CM-SM separation.



(a) System 1.

Figure 17.- Command module RCS helium tank pressure and temperature during entry.



(b) System 2.

Figure 17.- Concluded.

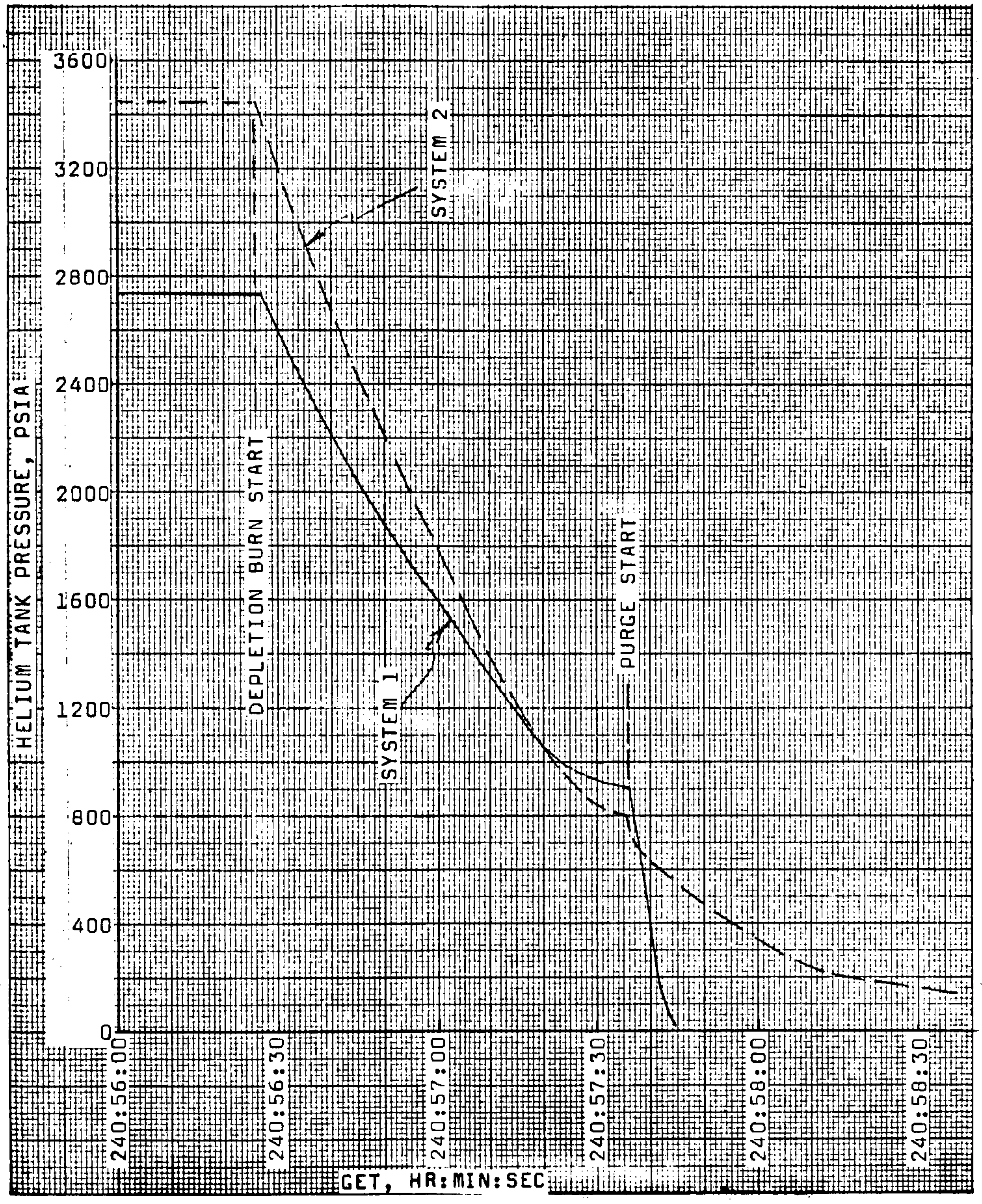


Figure 18.- Command module helium tank pressure during depletion burn and purge.

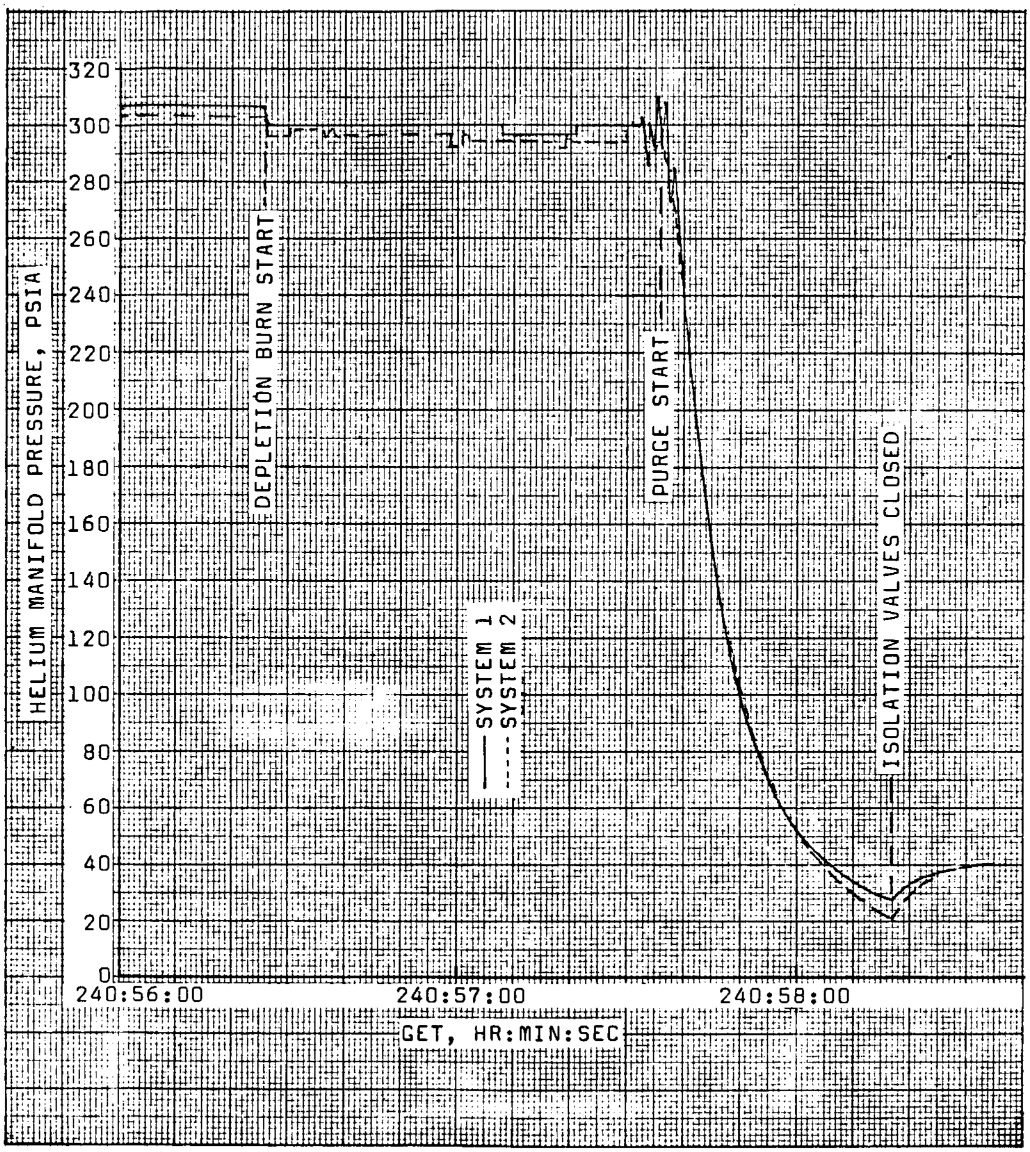


Figure 19.- Command module helium manifold pressure during depletion burn and purge.

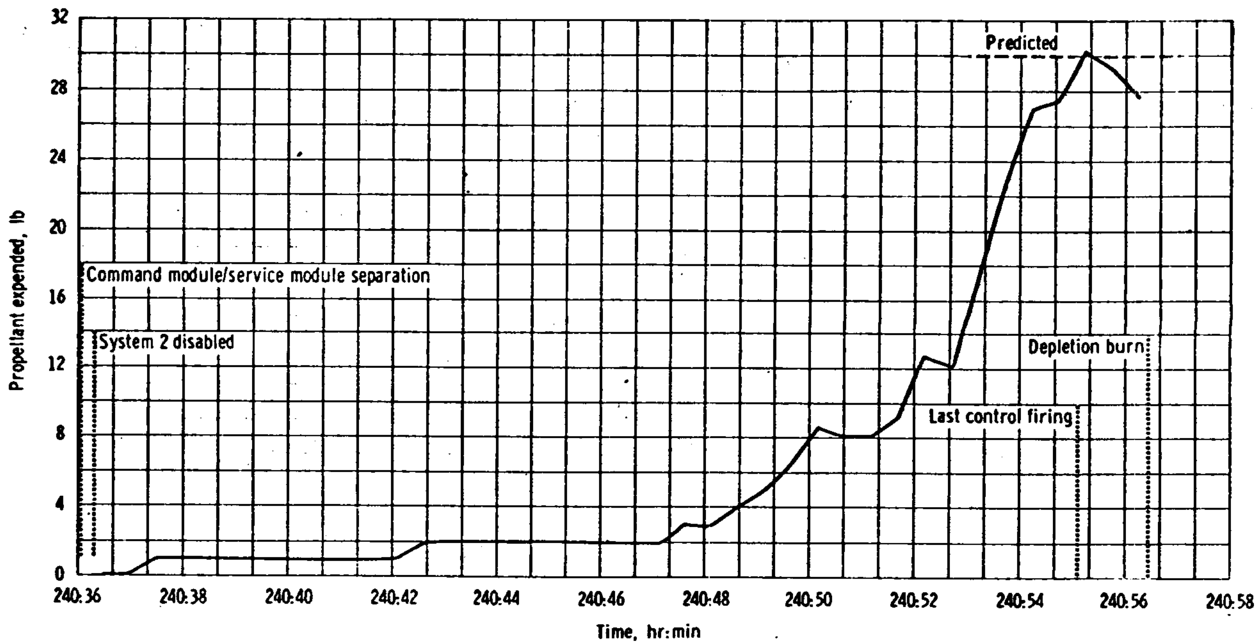


Figure 20.- Propellant expenditure from CM RCS.

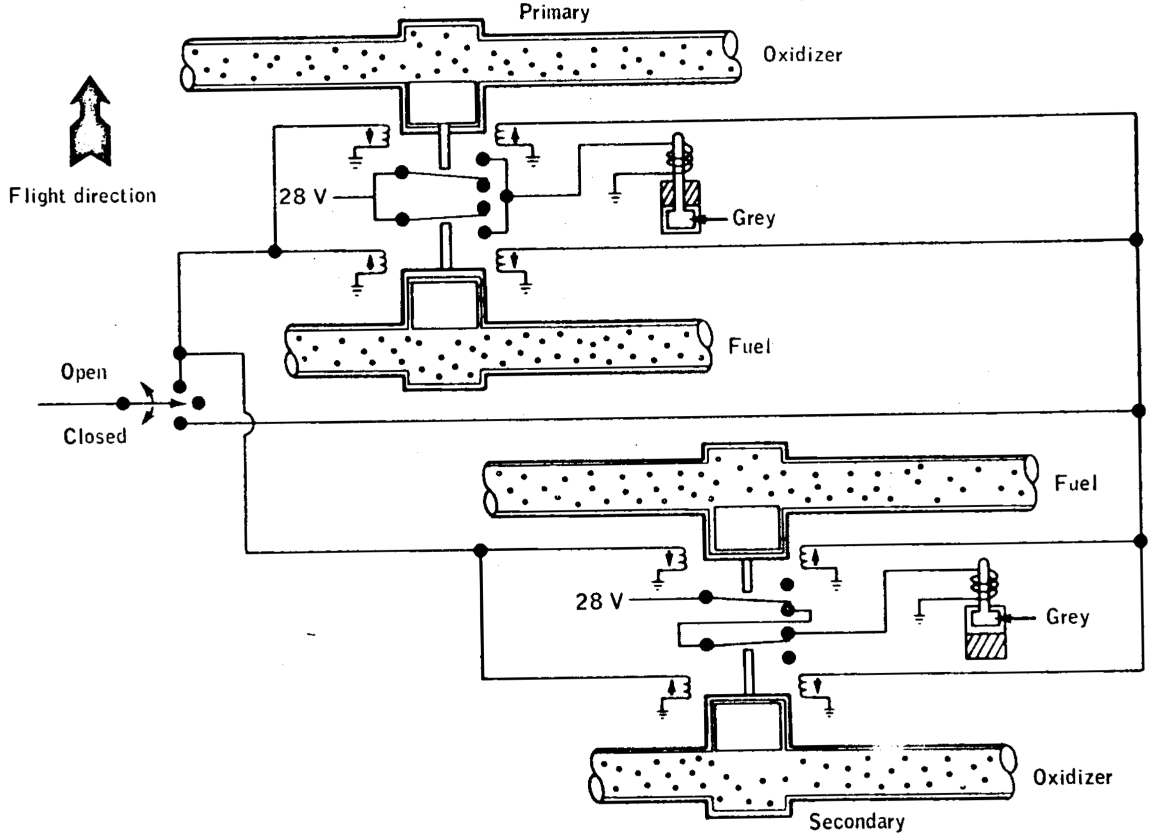


Figure 21.- Reaction control isolation valve.

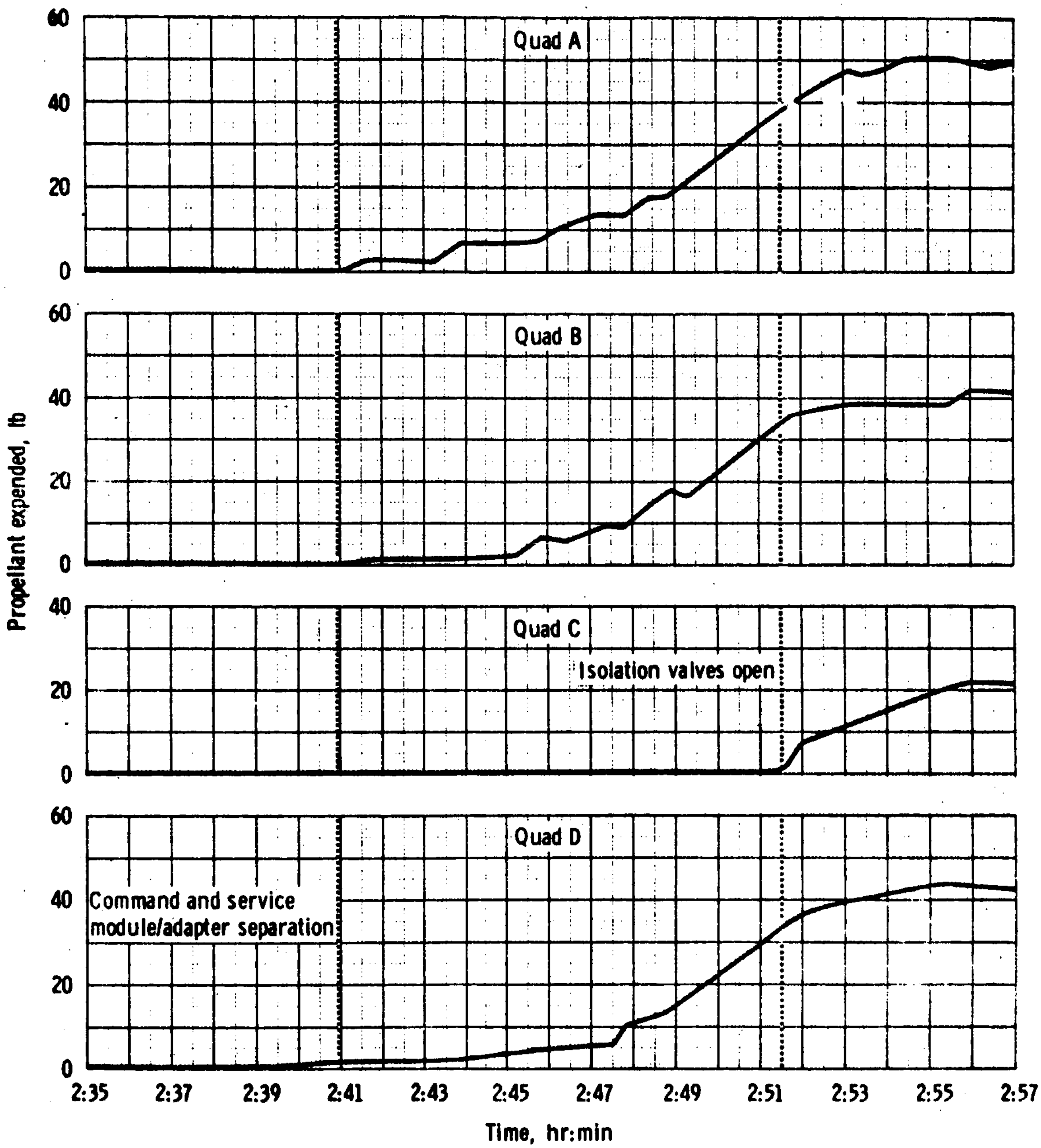


Figure 22.- Propellant expended showing inactivity of quad C.

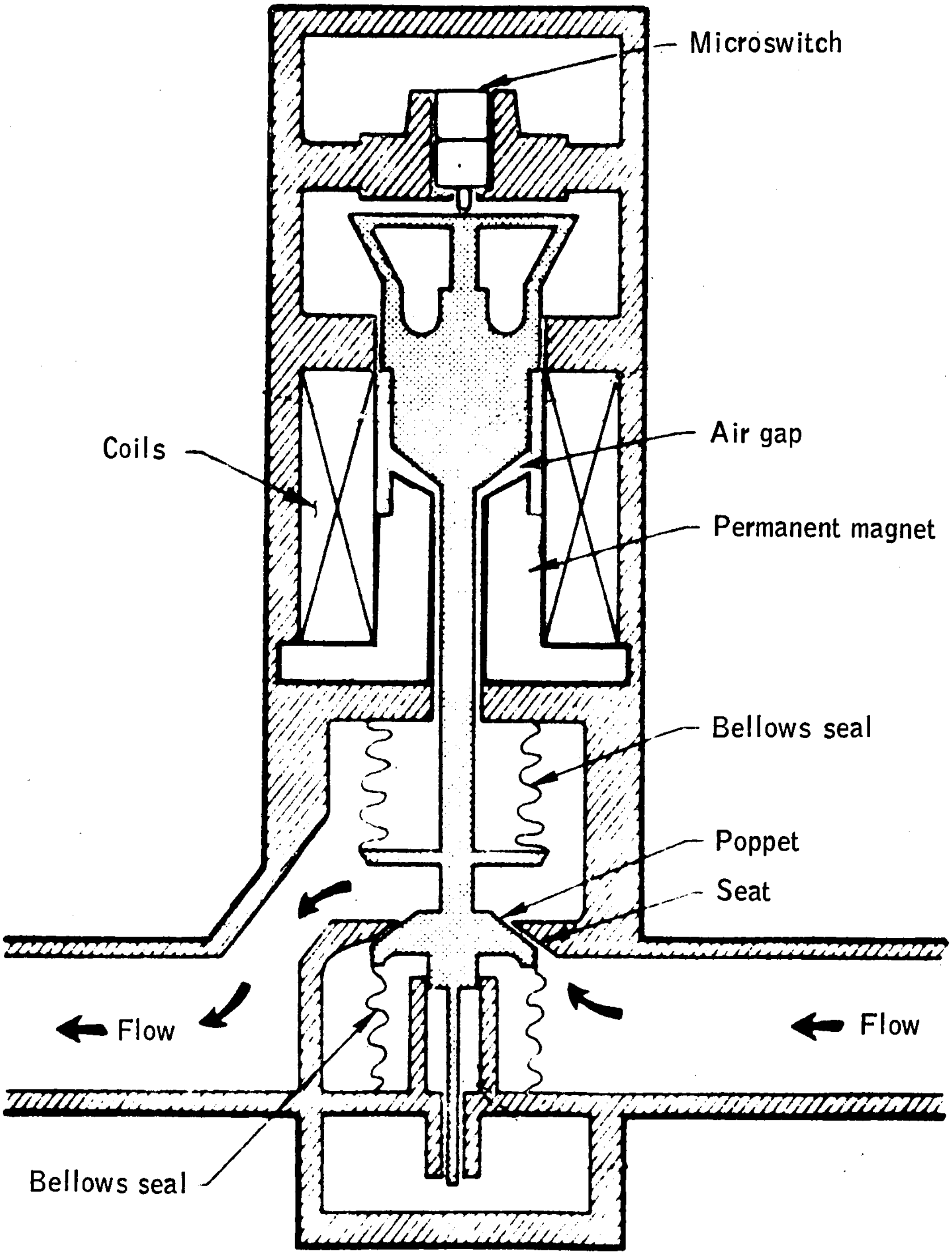


Figure 23.- Cross section of RCS isolation valve.